

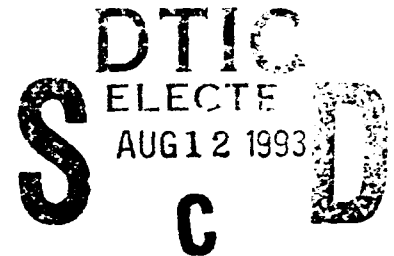
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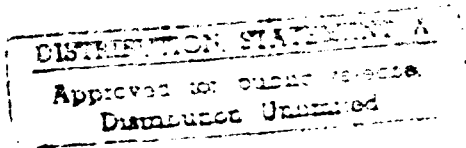
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U.S. ARMY INSTITUTE FOR RESEARCH
IN MANAGEMENT INFORMATION,
COMMUNICATIONS, AND COMPUTER SCIENCES



Technical Issues in Evolving to Integrated Services Digital Network (ISDN)



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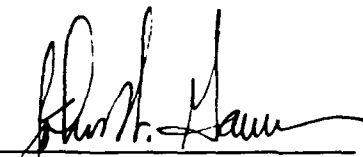



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THIS REPORT HAS BEEN REVIEWED AND IS APPROVED

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s/ 
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Executive Summary

The US Army Informations Systems Command (USAISC) and the departmental agencies within the command are undergoing major changes in the way USAISC does business as corporate entity. Changes are occurring in the automation of information and the exchange of information between the sustaining base in USAISC. ISDN is the objective configuration of the Army to support and manage this information flow. To effectively evolve to this objective configuration, the capabilities and limitations of ISDN must be understood so a comprehensive transitions plan can be developed. This Final Report is intended to provide findings and results stemming from the AIRMICS' ISDN Research Program that will enable the Army to make educated decisions on the use of current and proposed ISDN standards and applications as the Army transitions to the future. It also describes the general expectations, delusion, and surprises that we encountered while we were dealing with ISDN. Other key aspects of this report are:

- It examines the applicability, usability, and inter-operability of ISDN for a variety of present and future distributed, user applications. In order to make the findings and results as widely applicable as possible, the approach taken was to study the detailed nature of the services provided at the various ISDN user interfaces and compare these to the requirements of user applications.

- It delineates a detailed study of the ISDN user interfaces examining both the specifications for the interface as well as for specific implementations. This study includes the effects of noise and other impediments on the interface, the presence of improperly configured terminal equipment, and other anomalies that might be encountered in a general user environment.

- In support of this project, an ISDN Experimental Facility was established to provide the capability of developing testing techniques and procedures without disrupting the normal operations of the public network which is the ultimate target for the testing. This report describes, in great detail, the original vision, the actual implementation, problems that occurred, and limitations encountered during the set up and operations of the experimental facility.

- It also describes the specialized test equipment and test procedures which were designed and developed for this project. Data

from initial tests performed to obtain quantitative characteristics of the ISDN services were reported and analyzed.

- This report quantifies several factors in addition to performance that will have effect on the utilization of ISDN services. Although the research focused primarily on a set of technical issues in evolving to ISDN, a number of other factors, which are non-technical, but often have a direct impact on technical issues were also identified and addressed.

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Technical Issues in Evolving to Integrated Services Digital Networks (ISDN)

1. Introduction

It is our acknowledgement that the results and findings from the GIT's report¹ were extremely instrumental and widely used in preparing this document. Some of the research efforts were focused at issues in line with the Army's ISDN transition strategy and requirements that we gathered through meetings with various Army and DoD organizations.

Project Chronology

The dates for key milestones during this contract period are:

- | | |
|---|-------------------|
| • Contract award | 3 February 1989 |
| • Project kickoff meeting | 9 March 1989 |
| • BellSouth Enterprises participation | 15 July |
| • College of Computing/Electrical Engineering move to AECAL | 15 September 1989 |
| • Equipment order determined for AIRMICS | 30 September 1989 |
| • Permission to order equipment received | 12 October 1989 |
| • Initial implementation of S-Bus error injector | November 1989 |
| • Informal project review | 20 November 1989 |
| • ISDN lines installed | 30 January 1990 |
| • Formal project review | 15 March 1990 |

¹The Georgia Institute of Technology was the primary contractor for the project "Technical Issues in Evolving to ISDN", sponsored by AIRMICS. This work has been executed under contract DAKF11-86-D-0015-0022, GIT Project E-21-F31 (School of Electrical Engineering) and G-36-615 (College of Computing), during the period March 3, 1989 to November 3, 1990.

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2. Scope of this Report and Other Project Support

The primary scope of this report is limited to the results of the ISDN applications research conducted under the conditions that these results will provide an opportune foundation to serve the Army's needs towards ISDN transitioning. Where appropriate, findings from other studies are referenced and incorporated. All instances of results from other research or operational ISDN facilities are acknowledged as such. A major and active supporter of the current work is BellSouth Enterprises which has contributed a significant amount of expertise to this project.

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- CCITT Recommendation I.430 "Basic User-Network Interface - Layer 1 Specification," CCITT Red Book, Vol. III, Fascicle III.5, Integrated Services Digital Network, pp. 141-177, October, 1984.
- CCITT Recommendation I.431 "Primary Rate User-Network Interface - Layer 1 Specification," CCITT Red Book, Vol. III, Fascicle III.5, Integrated Services Digital Network, pp. 178-184, October, 1984.
- International Standards Organization, Draft International Standard 8877, Information Processing Systems - Interface Connector and Contact Assignments for ISDN Basic Access Interface Located At Reference Points S and T.
- "Performance Work Statement Technical Issues in Evolving to ISDN", contract DAKF11-86-D-0015-0022, GIT Project E-21-F31 and G-36-615.
- "User ISDN Implementation Strategies," Frost & Sullivan, Inc., New York, Winter 1990.

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3. Summary of the Project Technical Tasks

There were three sets of research oriented tasks specified in the statement of work for this contract

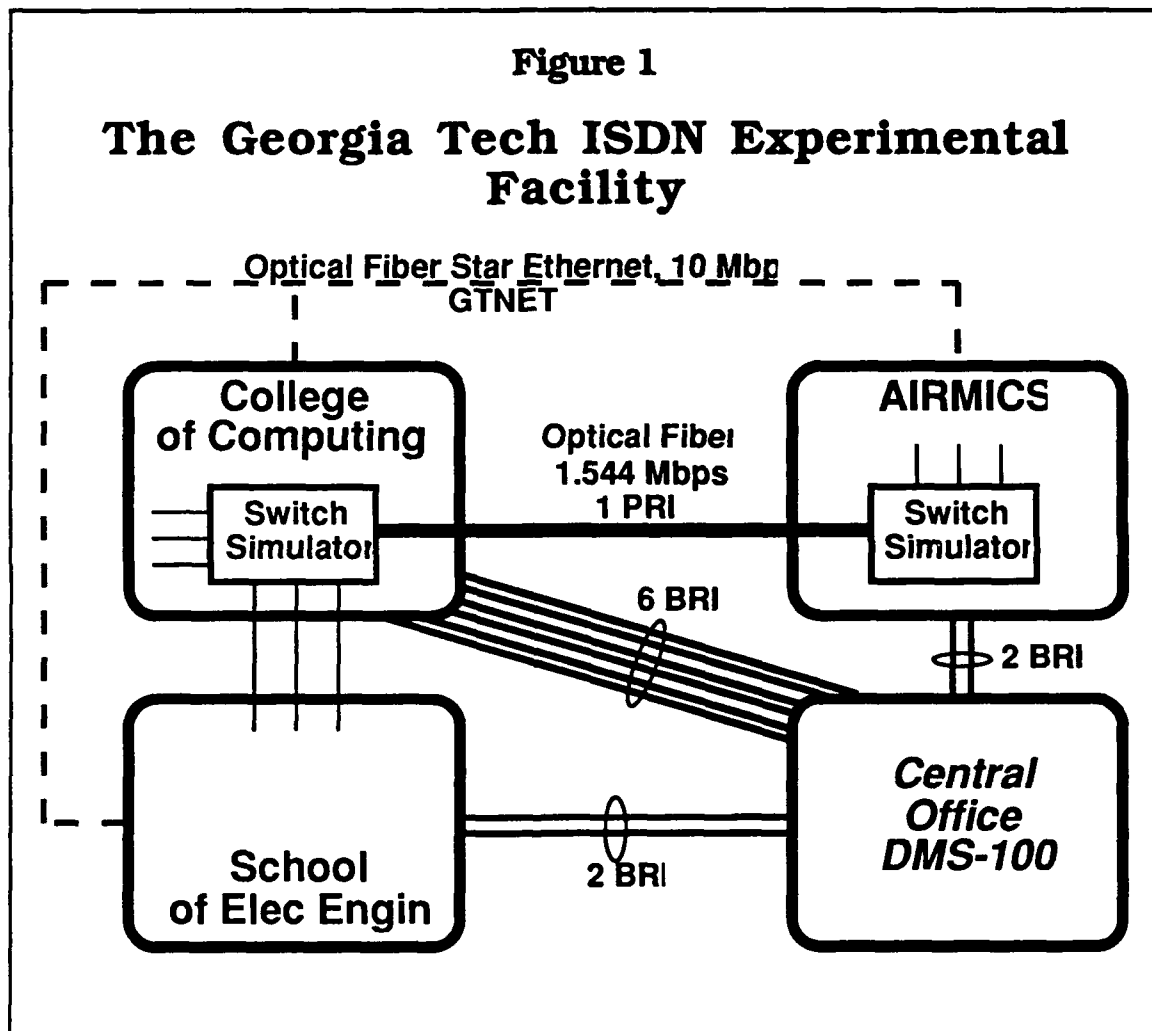
- The first set of tasks required the development of techniques and procedures to quantitatively measure and evaluate the performance characteristics of emerging ISDN services.
- The second task required the establishment of an ISDN applications research facility.
- The third set of tasks required analysis and comparison of potential ISDN services to existing services.

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4. The Georgia Tech ISDN Experimental Facility

This was the "second" task of the project; however, the existence of an operational experimental facility was essential to developing and verifying the measurement and evaluation procedures to be developed under the "first" task.

Original Vision for the Experimental Facility



The original plan for building an ISDN test facility was formulated around the concept that generic connectivity would provide the solution for applications testing. It was felt that three separate sites comprised of equipment of similar type would support test scenarios simulating many normal environments. It was envisioned that a site in the School of Electrical Engineering Communications and Computer Engineering area (the third floor of the College of Computing building), a site in the AIRMICS office area (located in the O'Keefe

Building on the Georgia Tech campus) and a site in the College of Computing Networking Laboratory would be interconnected (Figure 1). Both central office ISDN phone lines and lines provided by ISDN central office simulators connected via fiber carrying primary rate ISDN would be installed allowing testing of both the CO LAN environment and self-deployed post-based LAN. One site, the College of Computing Networking Lab, would be an experimental node with analysis and patching equipment. The other sites would be "standard user" sites with computers, terminal adapters, and supporting software - ISDN control software, ISDN applications programs.

With the fiber already in the ground on the Georgia Tech campus, the fiber connectivity was considered to be relatively easy. Special assembly pricing for phone lines providing ISDN service were established by Southern Bell, and ordering and installation were begun. Equipment was ordered to provide the patching and connectivity at all sites and ISDN protocol analysis gear was borrowed from BellSouth. As equipment arrived, wiring was installed and connections were completed. There were some problems with the installation of the equipment that were unexpected. These are discussed below.

One major purpose of the experimental facility was to permit interoperability testing of terminal adapter cards and other terminal equipment from various different vendors. Applications were chosen that would represent a cross section of what is needed in the office environment and an attempt was made to procure a version of these applications that would run in the ISDN environment. Some of the application areas were word processing, screen sharing, voice call management, and shared file serving.

Projected equipment on each node consisted of several PC/AT class machines, Apple/Macintosh computers, terminal adapters (both PC add-in cards and stand-alone); and, if possible, some type of monitoring device. Two sites were to include Teleos Central Office Simulators which simulate the ISDN service provided by AT&T 5ESS equipment. Since the "real" ISDN lines obtained from Southern Bell were serviced by a Northern Telecom DMS-100 Central Office, there was now a capability to hook-up and install any ISDN terminal equipment or terminal adapters regardless of which form of signalling it implemented — stimulus signaling on the DMS-100 or functional signaling being used on the 5ESS.

The original goal and plan were to have a test facility up and running within six months. This experimental facility was to contain sufficiently diverse equipment and applications software to be able to emulate the generic environment envisioned to be supported by ISDN-type services.

Planned Connectivity

As was stated earlier, the original ISDN network was to consist of two separate and distinct parts: that connected by the public central office and that connected by the customer owned PBX (simulation). It was envisioned that eventually (when equipment became available to do so) either or both of these parts would be interconnected using the Georgia Tech campus-wide ethernet network. Three sites were identified for placing equipment. These were the College of Computing Networking Laboratory, the Electrical Engineering computer cluster (the AT&T laboratory), and the AIRMICS' Research & Development Lab in the O'Keefe building on the Georgia Tech campus. The Networking Lab in the College of Computing building was to be the major experimental site housing test and patching equipment as well as computers for running applications. The other two sites were primarily for simulating the office environment in which ISDN was envisioned to be used. BellSouth was offered the opportunity to participate as a functioning node and some work has been done toward that end although the physical connectivity via the central office would be the only possibility as fiber is not yet available from the Georgia Tech campus to the BellSouth building.

Each site was originally planned to have several different vendor's ISDN PC terminal adapters for use in several different machines including IBM PC/ATs and PS2s and Apple Macintoshes. The AIRMICS node had some IBM PC/ATs and MacIIs. The Networking lab already contained several ATs and procured two PS2/model 80 IBM workstations. Apple MacIIs were also already available on a limited basis in the Lab. The EE node consisted of AT&T 6386 machines which were AT compatible. A Teleos ASK200 central office simulator providing 4 basic rate and 1 primary rate lines was ordered for the Networking lab and the AIRMICS lab. EE was to utilize only the Central Office Northern Telecom lines.

In summary, the AIRMICS central office simulator was to be connected to the College of Computing Networking Lab central office simulator utilizing optical fiber and all three sites (Networking Lab, AIRMICS, and EE) would be connected in star-fashion using the "real" ISDN central office lines through the central office at Courtland Street, Atlanta. This would allow the study of both generalized ISDN connectivity and post, private exchange ISDN service.

Implementation of the Initial Experimental Facility

The following activities were undertaken during the establishment of the ISDN laboratories at AIRMICS and at the GIT College of Computing.

- Identify hardware and software required
- Identify potential products and vendors

- Obtain products
- Check-out products
- Interconnect AIRMICS, College of Computing, and EE
- Obtain ISDN lines to Southern Bell switch

Connectivity Actually Established

Ten ISDN BRI lines were ordered from Southern Bell with funding from BellSouth Enterprises. Two of these lines were to be delivered to the AIRMICS lab, two were to be delivered to the EE lab and the other six were to be distributed into the Networking lab and surrounding offices for use in a real environment. Patching was set up in the data closet outside the Networking lab that allowed moving of the lines as needed to any point in the Networking lab. More patching was set up inside the lab itself for patching monitors and computers together and into variously configured lines. It was envisioned that several different configurations of lines would be necessary for complete testing: three of the lines were ordered with B channel packet switching available and the rest were configured with B channel circuit only.

For terminal adapters, several companies were approached. AMD, Hayes and Northern Telecom were the initial providers of terminal adapter cards for PC/AT class machines. Teleos and Vadis terminal adapters were later purchased since they also provided a more clearly defined application programming environment for different existing applications, although this did not solve the problem. Teleos, Northern, and Vadis provided call manager software which was useful in recording logs of phone calls and provided a directory for automatic call placement. Vadis also provided electronic mail delivery and screen sharing. Northern used the Microsoft Network interface which can utilize Word Perfect to work across the ISDN through a screen sharing package. Teleos provided the easiest interface to the programmer and thus was the platform of choice for doing in house programming of test tools. Also, others in academia were using the Teleos card and we were able to procure some third party software which was written to run on this platform.

Since there was no available ISDN card for the Macintosh computer, an external terminal adapter was necessary. AT&T 7506 ISDN telephone sets were used to provide this function in conjunction with software provided by Newbridge. This software allows sharing of files between IBM PCs and MacIIs by interfacing through the host computer's serial ports to the EIA232 interface on the phone sets. This link was limited to about 19.2 Kbits per second due to the nature of the host serial ports.

ISDN Wiring and Distribution

As was mentioned earlier, there are several different standards emerging for ISDN premises wiring distribution. No one has gained a firm hold on the industry so there is still some ambiguity in what wiring and connectors should be used. BellSouth is standardizing on the RJ45 connector for both S/T and U interface connections. But Northern is still making phones which use the RJ11 connector. There are other problems as well. Harmonicas, which convert a 50 pin phone connector into six RJ45 connectors, have different internal wiring standards. This is confusing and there is no set standard as to which of these should be used in general. Cables may be made straight or rolled. These terms refer to the way the color code is followed in crimping the RJ45 connectors on the ends of the 8 wire cabling that is used for ISDN connections. If both of the connectors have the same color code when looked at side by side, they are considered straight. If not, they are considered rolled. This could be thought of as reversing the polarity of the pairs in the cable since the wires are paired starting with the inner two and moving outward. But then this standard is also not universally followed. The rules and tricks of connecting ISDN devices together must now be learned on a per manufacturer basis with help from their installers. The hope is that someday, a general document will be available which will permit someone with general telephone knowledge to be able to connect any ISDN device.

Generally, ISDN wiring could be planned exactly like standard POTS wiring with one exception: consideration of the placement of the NT1, the Network Termination (NT) device which terminates at the "U" interface and creates the S/T passive bus interface. The NT1 requires power and may in turn provide power to the Terminal Equipment that it services over the 8 wire cables that are used to connect up to eight terminal devices to the NT1. This means that if the power to the NT1 goes out, the NT1, the Terminal devices will not operate, and thus all phone service disappears. This may be a real problem since the phone companies in the US do not plan to furnish power to the NT1 over the U interface. The consideration of the placement of the NT1's must take into account whether this phone service outage will be acceptable or not and if not, some sort of uninterruptive power supply must be used and all NT1s located near this device. Otherwise it may be that the NT1s may be distributed to the offices where the ISDN services will be terminated and powered from receptacles in the office. Since the U interface is two wire and the S/T interface is four wire some cost savings may be had by co-locating the NT and TE. But this must be considered carefully.

ISDN over the Campus Fiber Network

A pair of the campus optical fiber was allocated to carry primary rate ISDN between the Teleos Central Office Simulators located in the College of Computing node and the AIRMICS node. This is currently being accomplished by using a standard DS1 DSU/CSU which takes

the DS1 signals leaving the Teleos Central Office Simulator and transmits them over a fiber connection across the campus in a point to point fashion.

Fiber is not a trivial media to work with as connectors must be attached by someone with experience. Also, the political ramifications of procuring such a scarce resource, a pair of fibers installed in conduit underground, are not negligible. To use a single pair of fibers to carry 1.544 megabits per second when it could be carrying 10 megabits or 100 megabits, is considered wasteful to some. It required much discussion for the College of Computing to gain permission to use a pair of multimode fibers for this project though it was assumed to be of no consequence when the task was begun.

General Expectations and Disappointments

As was discovered after the installation process for the test facility was begun, the level of expectation for the setting up of the test bed was outside the bounds of reality. It was expected that both Northern Telecom and AT&T equipment would be supported by all vendors. This proved not to be the case — vendors initially supported only one or the other. It was expected that various pieces of equipment from different vendors would interoperate with other vendors' equipment. This also was a false expectation similar to the one that was prevalent when Ethernet first started appearing on computer equipment.

It was also expected that if you could imagine that ISDN worked in a certain way, it would. The operation of the passive bus was one of these. The Northern Telecom Central Office initially did not support dynamic allocation of B channels to terminal equipment. The B1 channel was allocated to the TEI 1 device and B2 is allocated to TEI 2 by the switch. This prevented all eight devices on a fully configured passive bus from having voice access. Only D channel activity is allowed to TEI3-TEI8. Other things such as the expectation that 22 gauge wire would fit into standard RJ45 connectors caused much wasted time.

Problems That Occurred and Limitations Encountered

The problems that occurred in setting up the test facility are of general interest since they help to describe experience in trying to be first at reaching some goal. The problems can be divided into seven major categories:

- Real problems with ISDN itself;
- Manufacturer implementation strategies;
- ISDN application software problems;
- Effect of ISDN on other application software;
- Support hardware and wiring;

- Dynamics of the ISDN equipment industry and marketplace;
- ISDN line problems.

Problems With ISDN Itself

Real ISDN problems are those considered to be directly caused by the ISDN standard itself. Some would classify the speed of the B channel as a real ISDN problem since it is slow compared to other local area LANs existing today. This is not considered a problem here, rather an application issue. Problems that are considered in this category are: the lack of coordination between B channels in the basic rate line making it hard to cascade B channels to add bandwidth; the multiplicity of standards for ISDN (CCITT, ANSI/T1, BELLCORE); and the fact that power is not provided by the network (is ISDN a single line service?).

Manufacturers Implementation Strategies

A problem that surfaced somewhat unexpectedly was that equipment would usually not operate with both the AT&T interface and the Northern Telecom interface. This meant that one piece of equipment was necessary to communicate over the central office Northern Telecom standard ISDN lines and another was necessary for the Teleos provided "AT&T standard" lines. Some software would work on one set of equipment and not on the other. So the amount of equipment necessary to do applications testing became much greater than expected. It was apparent that some software would have to be written to get complete connectivity of all of the pieces that were needed to do the testing envisioned.

ISDN Applications Software Problems

The major applications software specific ISDN problem is the lack of application programming interface specification. This often led to a complete inability to have inter-operability between different vendors implementations of software. Even where NETBIOS is specified as the interface, proprietary additions have been placed on top of NETBIOS for added functionality which often causes incompatibility with other ISDN interfaces.

Writing software for any of the equipment (except external TAs) proved to be a great challenge also. Most companies had modified an existing standard programming interface to adapt it to use with ISDN; however, ISDN provides both voice and data capabilities. Thus, those companies who used NETBIOS had to add capability. This meant that knowledge of standard NETBIOS calls was not sufficient to write software for these cards. It was difficult to find companies who had already documented the changes to NETBIOS that they had added so that we could begin writing code. This continues to be a problem. Any company that provided unmodified standard interfaces generally did not take advantage of any new features that ISDN allowed. This treated ISDN as a data pipe and required the user to do any negotiating of the channel through some

separate interface (such as the AT command set of the Hayes modems or the command set for the AT&T 7506). This was not deemed acceptable for the envisioned environment.

Effect of ISDN on Other Applications Software

Other application software problems include the applications themselves which will run on stand alone computers but are very complex when used in conjunction with ISDN interfaces. Configuration is a major chore when trying to bring up applications over ISDN. (A somewhat similar condition is found with X.25 interfaces.) There are many more variables to consider than those encountered in "standard" networking software. It is sometimes difficult to make applications work on top of services provided by the ISDN equipment. There is also the problem of the memory required by ISDN device drivers and Call Managers. There may be little memory left for other applications.

Support Hardware and Wiring

Support hardware was a major stumbling block for the test facility. Equipment that was ordered per manufacturers' specifications and sales information did not work upon arrival. Plugs, jacks, wire sizes, stranded versus solid wiring, color codes, pairing of wires, and connections between patch panels all became tedious and recurring problems that took much interaction with vendors and sales people to solve. This appears to be a problem of trying to use existing standards for wiring with a new service and not being able to get information distributed as to which standards are appropriate or specified with which parts of the ISDN specification. There are apparently different wiring specifications for the U interface than for the S/T interface. This is not the fault of vendors or manufacturers, but merely a lag in information distribution and a lack in solidification of the nuts and bolts of the standard.

Dynamics of the ISDN Equipment Industry and Marketplace

The type of industry into which ISDN was born is another major factor in implementing a facility. Much of the manufacturing sprung up overnight. But when the demand was not what was expected some of it quickly sank back into uncertainty. Northern Telecom discontinued its terminal adapter, which was one of the better ones when used in conjunction with Northern Telecom DMS100 phone lines. The card was intended as an example for others to follow and to show what ISDN services would provide as a bootstrap effort for the industry. It did its job well, but those that started using this card really had nothing to replace it when it was removed from the market. Another hardware and software manufacturer, Vadis, is in the process of trying to sell its hardware line and remain only as a software provider. These constant changes and the resulting uncertainties made it harder to obtain service for these components. Along with this, sales force

turnover made it very hard to reach a state of continuity and consistency in contacts with several vendors.

Shipping delays were a considerable problem in this project. Seemingly, many companies had product offerings that were ready to ship. But, apparently, most of these products were new and not in stock. They had to be built before they could ship. Teleos required a considerable lead time, part of which was our fault for not having the funds up front for the purchase, and part of which was Teleos' for the delay in construction and shipping. It was not until December 1989 that we received the boxes. Vadis had a similar problem. We ordered 5 Vadis terminal adapters, three for the AT platform and two for the PS2 platform. The PS2 cards were not in assembly yet (still apparently in beta testing) and so we took delivery of five cards for ATs with the condition that we would swap two for PS2 cards when they became available. The cards still are not available.

Software upgrades are coming out fast and furiously now since the standards are still changing. With Northern's move to functional signalling in the BCS29 and BCS31 releases, most companies that supported Northern are having to rewrite their code to this new standard. AT&T is apparently changing some of their standard also and if BellSouth goes to the Bellcore standard, things may have to change more still from the TA and TE manufacturers standpoint. Software upgrades are not cheap and the ongoing changes are causing problems with our connectivity. In moving to 2B1Q for the "U" interface, most of our TE type equipment is having to be changed out. Northern is doing this free through BellSouth but this also means that our phone sets must be changed. This is not a mandatory upgrade (going to 2B1Q) but is desirable from our perspective. This change will aid in keeping current with the industry.

BCS31 provides functional signalling from the Northern switch at the central office. But there are still more incompatibility issues. AT&T phone sets will not work on Northern functional lines even though 5ESS lines provide functional signalling. It is apparent that the "standard" issue is not going to be solved for a while.

ISDN Line Problems

Problems resulted from being a early customer for non-tariffed service from our local Bell Operating Company. Being the first non-internal customer for DMS100 lines gave us first hand experience with the phasing in of a new service. We helped to trouble shoot the process of ordering lines (with Southern Bell and the Georgia State Department of Administrative Services, the telco for state entities), with all the associated variables that needed to be set by the line translations. Billing was another area that provided interesting experiences. Since ISDN services are not currently tariffed, negotiations on what was to be charged for were carried on by several groups inside the phone company and ourselves. Federal regulations also had a part in this

confusion and may need to be modified to fit the new service provided. (For example, Federal regulations require the access charge to be assessed per telephone number not per access line.)

5. Instrumentation for the Experimental Facility

Traffic Loader and Tester

Two types of connectivity are available with ISDN: voice and data. Also, with data connectivity there are two types: circuit switched data and packet switched data. Testing in this environment requires several types of tools. One tool that has been missing in the data realm for some time is a device which will originate data traffic, send it out over a data circuit and terminate the data, keeping complete statistics on the delays experienced by the data in transit across the data circuit. Such a device has been constructed in the Networking Laboratory in the College of Computing and is called the Character Timer. A companion device, the Packet Timer, has been constructed and is functional although not to the degree of the Character Timer.

It is important to understand the value of such a device. In the voice world where circuit switching is used, delay of the voice data is constant. It is only the call setup time that varies. Much testing has been done to characterize the delays involved in call setup for voice switches. But this has not been the case for packet switches where each piece of data may experience different delay as it traverses the system. To understand the system, one must understand the interrelation between data loading, window size in windowed protocols, errors, and throughput. This is a non-trivial task even in the simplest networks consisting of two terminals and one packet switch. Delay is directly proportional to loading and errors but inversely proportional to window size after some startup function. Optimizing performance in such a system requires fine tuning and one of the only good indications of performance that is valid is end to end delay of the data through the system.

The Character and Packet Timers maintain a history of the delay experienced by each and every character/packet that was injected into the system and present that data as a histogram on completion of the experiment. It is envisioned that in the future, snapshots of the histogram at various points in experiments will be kept for later analysis. In a well functioning packet switching system (a statistical multiplexer) the delay histogram looks like a thin Gaussian curve around some mean. More loading is inserted into the system the curve may fatten out and even take on some other apparent Gaussian overlays on top of the original curve. This is normal and consistent with expectations of statistical systems. But as the loading increases or errors are introduced, the curve begins to smear across the range of the histogram and the delay has essentially no mean, becoming totally random across some range. This means that the system is getting out of its proper range of operation. It is important to recognize the points at which this happens so that network designers can allow for backup and redundancy where necessary. This has not been done consistently in the past.

An important part of this research is to characterize ISDN's packet switching services as to their end to end delays under various loading and error conditions so that these points of failure can be determined. It is also necessary to understand the end to end delays and the delays associated with call setup on of the circuit switching mode of ISDN connections. These results are all anticipated in future work.

Three general capabilities that should be available in any data communication testing facility are

- The generation of traffic loads
- The measurement of delivery delay for traffic
- The measurement of effective traffic throughput

There are certainly a number of other specific characteristics that should be examined and quantified to completely describe performance such as:

- Call set-up delay
- Call disconnect delay
- Reliability
- RESET indication rate
- Protocol robustness

However, these will be handled by other aspects of the experimental facility.

Functional Requirements for Traffic Loading and Performance Testing

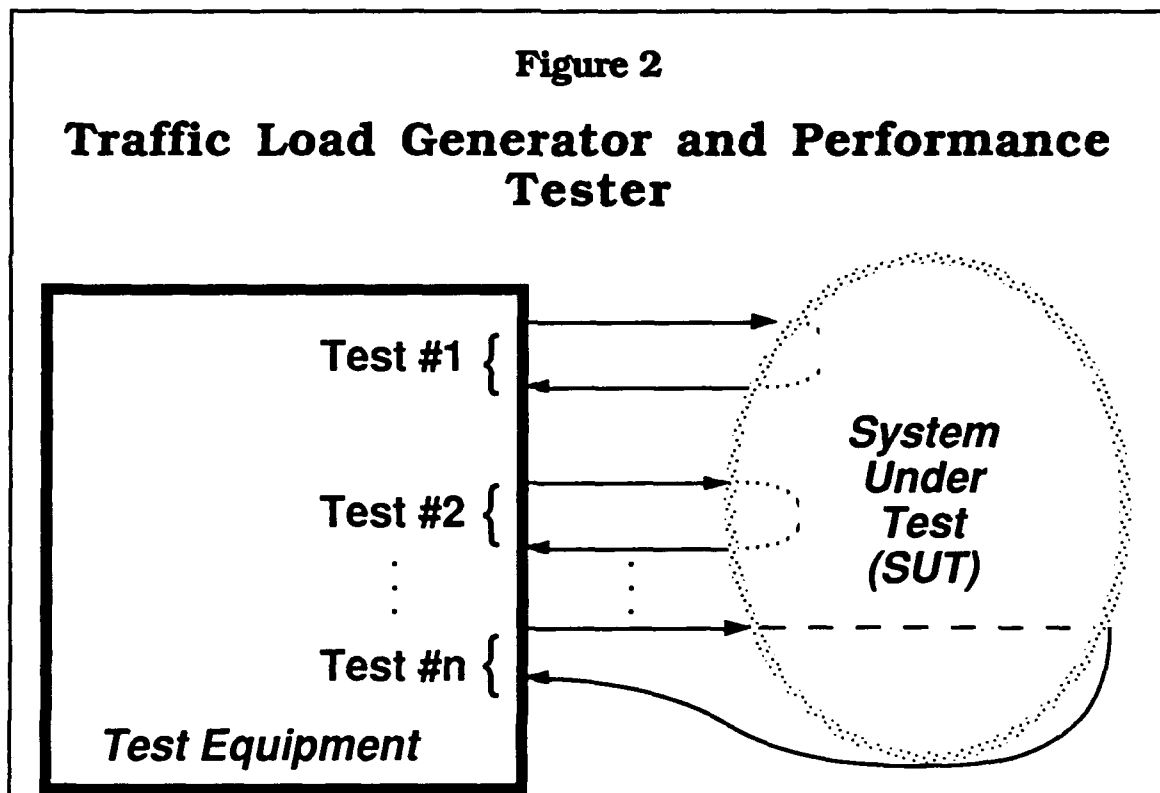
Perhaps the most important lesson that has been learned in previous performance testing projects conducted in the Computer Lab was that averages are an inadequate characterization of almost all performance statistics. It had become abundantly clear on previous projects that averages hid the interesting or useful data. It had been found that presenting the actual observed data distribution, in the form of a histogram or some other appropriate graphic, often enables the experimenter to gain valuable insight into the functional operation and performance of the system under test.

The general functional requirements established for the traffic loading and performance testing equipment were developed during a number of previous performance testing projects.

- The test device should be capable of generating traffic of the required type: characters, data link frames, network layer packets (e.g. X.25), or whatever is appropriate for the layer under examination.
- The test unit should be capable of generating traffic described by a variety of probability distributions such as: poisson traffic generation, uniform distribution of time between traffic units, constant time between traffic units, minimum time between

traffic units (traffic is sent at the maximum rate possible by the load generator), or have the time between traffic units governed by flow control imposed by the access port of the system under test.

- The traffic load generator and performance tester should be a separate and independent piece of equipment, i.e. these functions should not be implemented in one of the switching nodes of the interconnection subnetwork. As shown in Figure 2, this will permit the traffic to enter and leave the System Under Test at different access points (i.e. ports) and still be directly attached to the test equipment. This permits the testing of the performance of paths thru the System Under Test (SUT) that do not have to close on themselves within the SUT. Exiting the SUT on the far side is quite acceptable and allowable since the delay in the line connecting the exit port to the test equipment will have a fixed delay that can easily be measured and subtracted from all delivery delay measurements.



- It is also desirable, from the point of view of cost-effectiveness, that the test equipment be capable of running multiple tests simultaneously. It is essential that simultaneous tests be performed on many of the different types of systems that are tested. Simultaneous, parallel tests are required to "load down" the SUT and to determine if there are any systematic

differences in the performance delivered or attainable at different parts of the SUT.

- Some automatic analysis of the test data and graphical presentation of the results are essential functions of the tester. Automatic scaling of the test results is desirable to provide easily interpreted graphs. In accordance with the requirement stated above, the results of the test should be presented as histograms of the distribution of delivery delays. In addition, the total throughput achieved for the period of the test should be calculated and presented. A capability to store test results should be provided so that the results of various test runs can be easily compared, again, graphically.

Performance Test Equipment Developed at Georgia Tech

Several pieces of equipment, which were designed and developed specially for this project, were described below.

The "Packet Timer"

The current work at Georgia Tech on the development of load generator and testers is at the Network layer, specifically the X.25 Sub-layer. This is an area in which performance measurement is of high interest to a wide variety of parties including users as well as systems developers; however, there is very little equipment available to help them.¹

An important operational requirement for the Packet Timer is the capability to run simultaneous tests on a number of X.25 ports. Since the number of simultaneous tests desired could be quite large, this created a subsidiary requirement that the cost per port be low. The decision was made to utilize a multi-channel, programmable communications board that fit in the IBM AT personal computer.

The programmable interface board has sufficient power and memory to permit the complete test procedure and data gathering to be run on the board requiring no interaction with the AT except to set the test parameters, start and stop the test, and display and store the test results. Since the objective was to measure the performance, i.e., throughput and delivery delay, of the store-and-forward subnet, a complete implementation of X.25 is not required — there is no need for error or exception handling, special feature facilities, negotiation, etc. Basically, all that is required is the data transfer portion of the X.25 procedures.

¹The only units that we know of that test packet performance — throughput and delivery delay — were both developed in England. The first, Microflood, was developed by British Telecom. Although it does test up to 16 ports simultaneously, it is quite expensive — approximately \$100,000. The other unit developed by Cybernation is cheaper, approximately \$20,000; however, it does not test as many ports. Neither unit has ever established a market in the U.S.

The basic capacity of the interface board selected is four synchronous lines. The board also has the capability to add four more ports; however, before doing that we must establish that the processor can handle that many interfaces correctly and still maintain accurate timing. Another capacity factor that must be evaluated with respect to maintaining accurate timing is the number of logical channels/virtual circuits that may be active simultaneously. Obviously, performing a large number of simultaneous tests with one board is desired, but only if the test results remain accurate. Another mechanism to increase the number of simultaneous tests is to utilize multiple boards in the same AT to reduce the cost per test port. Since the AT itself is not involved in any manner during the running of the test (the board even has its own clock) this is certainly an attractive option that this approach provides.

The data reduction and presentation for the Packet Timer is the same as for the other test units — a single number for the average throughput per unit time and a histogram chart showing the distribution of delivery-delay times.

The Current "Character Timer"

The Character Timer test units in the Networking Lab have gone through several "generations" of development — at least three. The motivation in each redesign was the utilization of a new, hopefully better, implementation platform and the improvement of the user interface and data presentation.

The Character Timer has just recently been implemented on the same platform as the Packet Timer, a programmable communications interface card for the IBM AT. Obviously, there are great benefits in reducing the number of different pieces of test equipment that must be maintained in the lab. In addition, the use of this card makes it very easy to implement a multi-port tester to run simultaneous tests easily and economically. It is clear that all of the test units should be implemented on the same platform if that is possible. As development of such units continues, there may be further changes in the host platform utilized; however, the basic concept, and even many of the details, will remain unchanged.

Protocol Monitoring and Analysis

Monitoring of the ISDN protocols was necessary for several reasons. It was at times necessary to monitor the ISDN lines to locate problems when trying to connect different vendors' equipment together. Also, with the large number of sometimes confusing parameters necessary to be set for configuring an ISDN TA, mistakes were sometimes made which required monitoring the line to find. There was a definite learning curve involved in becoming adept at connecting and running these devices and that curve was shortened by having realtime

monitors. It cannot be overstated that startup functions in any field have a break in period that requires users to take an active part in the analysis and configuration of components. This will be a challenge for most office environments for the next few years since most of these groups do not expect to have to keep technical staff on hand to troubleshoot low level problems.

The original concept was that the monitoring of the ISDN protocols and their analysis under operating conditions could be performed utilizing commercially-available ISDN protocol analyzers which were beginning to appear on the market. In general, this turned out to be a suitable assumption; however, it was quickly learned that not all ISDN protocol analyzers are "equal". Further, this particular type of protocol analyzer was still being developed and/or refined by nearly all of the existing suppliers, and the capabilities of the various analyzers were not fixed nor common across the industry.

A Tekelec Chameleon 32 has been furnished on temporary loan by BellSouth Services Science and Technology for use in the Networking lab. This device provides excellent breakout of all layers of ISDN protocols and a history mechanism that allows saving to disk files of large amounts of data for later display. It will act as both monitor and simulator for apparently any configuration of ISDN equipment and both AT&T and Northern Telecom equipment. There were several times that problems could not have been solved, or at least not as readily, without this piece of equipment.

The Teleos ASK200 has some built-in monitoring and analysis features that make it usable as an ISDN monitor. It will show activity on the line and a display of the bit fields in the ISDN frames being exchanged across lines connected the ASK200.

Controlled Error Injector for the ISDN S-Bus

It was felt at the beginning of this task that some means of injecting controlled errors into ISDN connections would be necessary to gain a full understanding of the protocols involved and the interactions between the layers that ISDN provides. Random errors, which one would normally expect to see, would, in general, only succeed in causing the link to be lost and so only adding delay as the link was reestablished. Controlled errors could instead be used to analyze the protocols and see where problems may occur in particular environments. It may be that these environments will never exist, but the understanding gained by the analysis is important to the goals of this project.

One of the important research goals of the project was to perform a close examination of the ISDN control protocols, particularly those used on the D-Channel of the Basic Rate Interface, from the points of view of correctness, performance, fairness, and robustness. Although

there have been previous studies of some of these factors, there was no work identified that addressed the last factor of robustness with substantiating experimental work. To accomplish this work there is a requirement to be able to selectively monitor and modify the bits in the various channels on the S-Bus as if they had been modified by noise.

The passive bus configuration is one place that error testing is envisioned as necessary. What if all devices on a passive bus assume that they have the channel and begin transmitting? What happens to the CO switch? Does it reconfigure or go into diagnostic mode? If so what is the delay incurred on each of the stations on the passive bus? If the echo bits in the frame level data unit are manipulated in a certain way this error can be inserted and the results observed.

An initial design was begun on an electronic device which would intercept and repeat an ISDN BRI line such that signals coming in would pass through with only minimal delay and very specific changes. For example, if a random bit were flipped, the checksum on the frame level data unit would appear to be invalid and thus the frame would be rejected. This would not allow changes and errors to be inserted into the packet/network layer for testing there. So, the design was extended to allow the addition of an intelligent monitor on the line which would understand the framing and control information of all layers and allow modifications to packets or frames and recalculate the checksum and reinsert it. This would preserve the link layer integrity while inserting errors in specific places.

Direct Injection of Noise

Direct injection of noise in the S-Bus signal stream might have worked; however, it is likely that most noise hits on the bus would corrupt the signal so much that the physical level of the TE/TA or the NT1 would force a complete disconnect and reinitialization process. To exercise and test the error recovery capabilities of the D-Channel Data Link Layer Protocol, access procedure, and control procedures would require more selectivity and finesse in how the errors are injected. The errors must be injected specifically into the D-Channel time slots on the bus signal and they must be linked so that the coding rules of the physical layer, modified AMI, were not violated. The error would then pass the D-Channel Physical Layer and be presented to the D-Channel Data Link Layer as "a good Physical Layer bit stream."

An Example Test — D-Channel Access

Having the capability just described would permit the execution of some rather unusual tests. One question that holds continuing interest concerns the D-Channel access control mechanism. The purpose of a D-Channel message is indicated by its address field specifically the SAPI portion, Service Access Point Identifier. The access control procedure for the TE/TA's is that priority is given to

the transmission of messages with the lowest address, i.e. SAPI "0" designates D-Channel messages involved with circuit switching control of the two B-Channels. If there is conflict with two TEs or TAs sending the same SAPI, then the tie is broken by the TEI, Terminal Equipment Identifier, which is in the second octet of the address field and is never duplicated on a S-Bus. All of the bits received by the NT1 on the D-Channel from the TE/TAs are echoed back to the TE/TAs on the other pair of wires in the S-Bus. A TE/TA attempting to access the D-Channel starts to send its LAPD frame and listens to the echo bits. If the TE/TA hears an address lower than its own, it immediately stops transmitting and waits until later to attempt access again.

What do you suppose would happen if all of the TE/TAs attempting to access the D-Channel observed that the "echoed address" was a higher number than their own? It is not at all clear from the protocol description what would happen. It appears that the results might be much more implementation dependent than protocol definition dependent. In any event, the ability to force the D-Channel bits to all "1s" without causing a disconnect would allow the results to be observed.

This is just one example of the numerous tests of the D-Channel operation that could be performed utilizing such a capability.

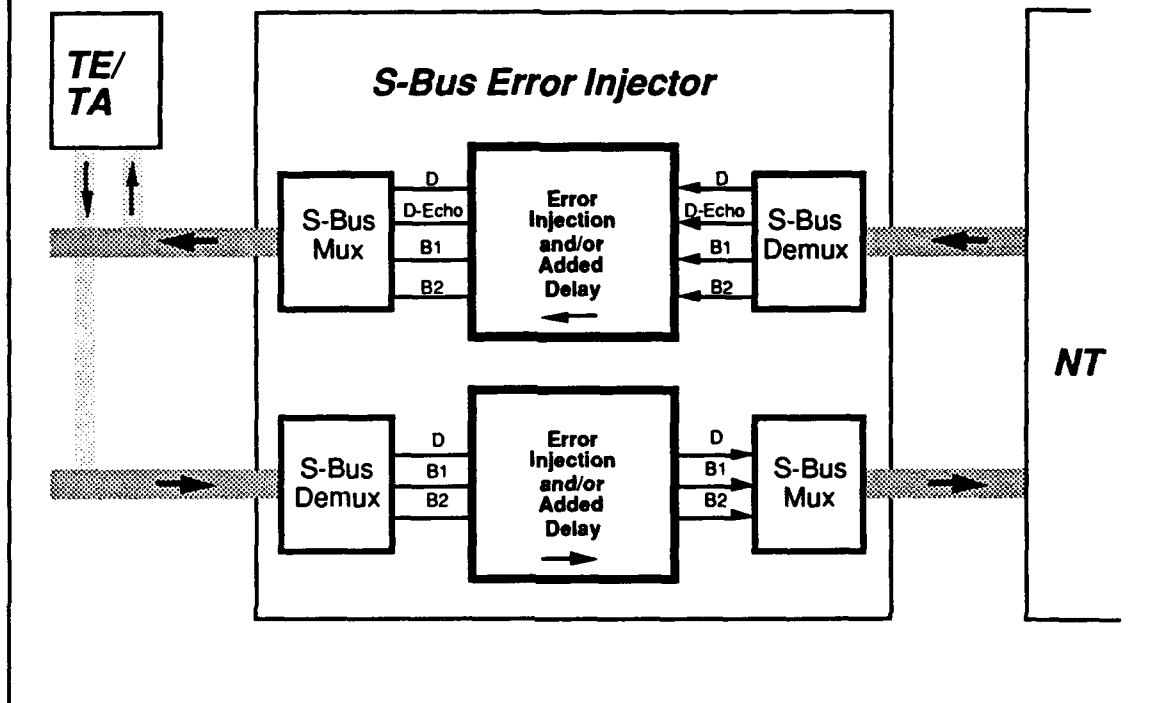
Functional Requirements of the S-Bus Error Injector

In order to perform its functions, the S-Bus Error Injector (Figure 3) must become an actual part of the S-Bus completely intercepting it, removing original signals, and transmitting the modified ones. The first capability that the unit must have is the ability to demultiplex the S-Bus signal into its component channels — NT1 to TE: D, D-Echo, B1, and B2; TE to NT1: D, B1, and B2. After the individual channels have been separated, then errors can be selectively inserted to examine their effect on the protocols of the specific channels.

Design and Implementation of the S-Bus Error Injector

The initial design of the error inserter has been completed; a device has been constructed which, when inserted into an S/T link between an NT1 and a TE, will allow transparent operation of the TE. The next step is to add the intelligent processing to this device to allow the controlled error injection. Neither of these steps is trivial. Since most ISDN chip sets are VLSI, knowing the schematics of these chips is not necessarily helpful in the design of discrete circuitry. Several different designs were contemplated before a successful one was found. Also the speed at which the intelligent processor must run to analyze the bit stream coming in at 192k bits per second in each direction is quite high. This last part of the project is still under way.

Figure 3
ISDN S-Bus Error Injector



ISDN Central Office Simulation

An important aspect of the development of the testing program was a need to have an experimental environment in which testing procedures could be tried out with no danger of causing problems for others. Of course, there were ISDN service lines providing access to a real ISDN central office; however, it is easy to imagine problems that might result from "playing" with a real switch that itself was still under development and field trial to some extent. It would certainly not favorably impress one of our major ISDN research supporters, and the effects on the other "innocent" subscribers were certainly unpredictable. (Needless to say, there were several problems with the service on the "real" ISDN lines; and it was comforting to say that the experiments to develop testing techniques definitely were not the cause of those problems.) The answer was to use an ISDN central office simulator which was available as a commercial product.

The Teleos ASK-200 Central Office Simulator

Two ASK-200 Central Office Simulators were purchased from Teleos, Inc. of New Jersey. These simulation units were described as having the following capabilities:

- Provide Basic Rate Access (BRI) ISDN service lines fully emulating the actions of the AT&T No.5ESS central office running the AT&T ISDN software, release 5E4.2. (Of course, the state of development of the software for the simulators and the features that it supports is a "moving target" just as is the state of development of the software for the real No. 5 switch.)
- Provide Primary Rate Access (PRI) ISDN lines that could be used to interconnect two simulators.
- Miscellaneous monitoring and control features added to the simulator to assist in developing terminal adapters, line cards, etc.

The experience of installing the two simulators was actually quite simple. However, there were a few problems encountered. It was originally assumed that the Teleos ASK200 would allow PBX type connectivity to the local site and then provide remote connectivity over the central office BRI lines provided by Southern Bell. This turned out not to be possible. The ASK200 will only communicate between like boxes and over primary rate ISDN. Also, at this time the ASK-200 would not support the Northern Telecom standard. Since primary rate was not available, an alternate approach was used. DSU's providing T1 type connectivity over fiber were installed in the AIRMICS lab and the Networking lab. These were connected using the campus fiber which provided DS1 transmission between the two labs. These will be connected to the two Teleos ASK200's to provide the backbone connectivity between the two sites.

Status of the Central Office Simulation

The two simulators were installed and became operational. They have operated as expected both when connected directly together while both were located in the College of Computing Networking Laboratory and are expected to perform as well when interconnected over the DS-1 fiber link between the Networking Laboratory and the AIRMICS Lab.

The simulators have fulfilled their intended role of providing an isolated ISDN environment in which there was total freedom to experiment.

6. Project Results

This section documents the activities which took place under each of the tasks and the results of the work performed.

Analysis of the ISDN Protocols

The task plan identified the D-channel as an area for research and performance analysis. A doctoral student within the College of Computing examined these protocols and prepared his PhD thesis entitled "Analytical Studies of D-Channel Traffic". This thesis contains a theoretical analysis of the D-channel and its capabilities. The thesis is summarized in Appendix C.

Functional Tests and Evaluation of ISDN Services

Although this project was focused primarily on a set of "technical issues" in evolving to the ISDN, a number of other significant factors were identified during the course of the project — some of these were technical while a number of these other factors are non-technical but often have a direct impact on technical issues. They are identified and discussed here to emphasize their importance although the investigations of many of these issues are far from complete.

User Acceptance of ISDN Services

In general, ISDN user acceptance has been very slow with the only incentive being free or reduced costs for ISDN services for users currently experimenting with ISDN via telco-sponsored ISDN trials. There have been no specific hard dollar cost savings offered by ISDN that would spur users to implement this new technology. An application such as the Visicalc spreadsheet, that fostered growth in the personal computer market, has yet to be uncovered for the ISDN market. In addition, users with large investments in their private networks or those with wideband communication requirements are not eager to convert to ISDN. This slow acceptance of ISDN is reflected in the insignificant implementation of ISDN lines to date. As of the end of 1989, there were fewer than 100,000 lines of ISDN in service.

Some of the reasons the ISDN market has been slow in taking off are that only special ISDN tariffs are available, standards seem to be a moving target, users cannot connect separate islands of ISDN, and ISDN CPE equipment is available but is not inter-operable.

ISDN Applications

The ISDN Environment for Applications Software

The applications software environment provided by ISDN connectivity is certainly no worse than that provided by POTS. The lack of the analog conversion and modulation/demodulation necessary seems to decrease the errors experienced over standard modem provided connectivity. But, in this project connectivity has been established only over a single CO.

Those applications which were designed with ISDN in mind, providing calling line ID and multiple channel utility, are perceived to be more useful than any existing counterpart over standard phone service. This brings the service provided by the phone company one step closer to that service provided by local area networks.

ISDN Applications Examined by This Project

A number of applications utilizing ISDN services were examined during this project. Some of these examinations were in the form of extended demonstrations while others were actually utilized by project team members during the project.

- Word Perfect running over the Microsoft Networks provided over the Northern Telecom ISDN card

- ISDN call managers running on Northern Telecom cards, Vadis cards, and Teleos cards

- Video conferencing equipment provided by PictureTel

- Screen sharing software provided by Vadis and Northern Telecom

- Electronic mail provided by Vadis

- Disk sharing software provided by Newbridge over PCs and Macs

- Disk sharing inherent in the use of the redirector provided by the Vadis/Novel combination

- IP over ISDN provided as experimental software by Dory Leifer of the University of Michigan in conjunction with equipment and software from Teleos and Rockwell/CMC. This included telnet, ftp, rlogin, ping, and other standard network utilities from the UNIX suite.

- ISDN protocol analysis provided by Tekelec through BellSouth Science and Technology.

As was previously mentioned, the one greatest stumbling block to applications testing was the lack of a ubiquitous interface for programs running on the ISDN hardware environment. Even the platform provided by Vadis, which includes COMM interface, REDIRECTOR, NETBIOS (extended), and a hardware interface, could not fit all applications directly since there is the need to dial up from one site to another to gain connectivity over ISDN and standard applications (those not designed to go over a network) do not have provision for this. Other network applications assume certain tools at their disposal including address and name resolution, dynamic address assignment, and broadcast facilities. No address resolution is provided and very little is done to allow automatic timing out of connections when idle. Applications programming interface standards are the single greatest need in the ISDN industry today.

What is an "API"?

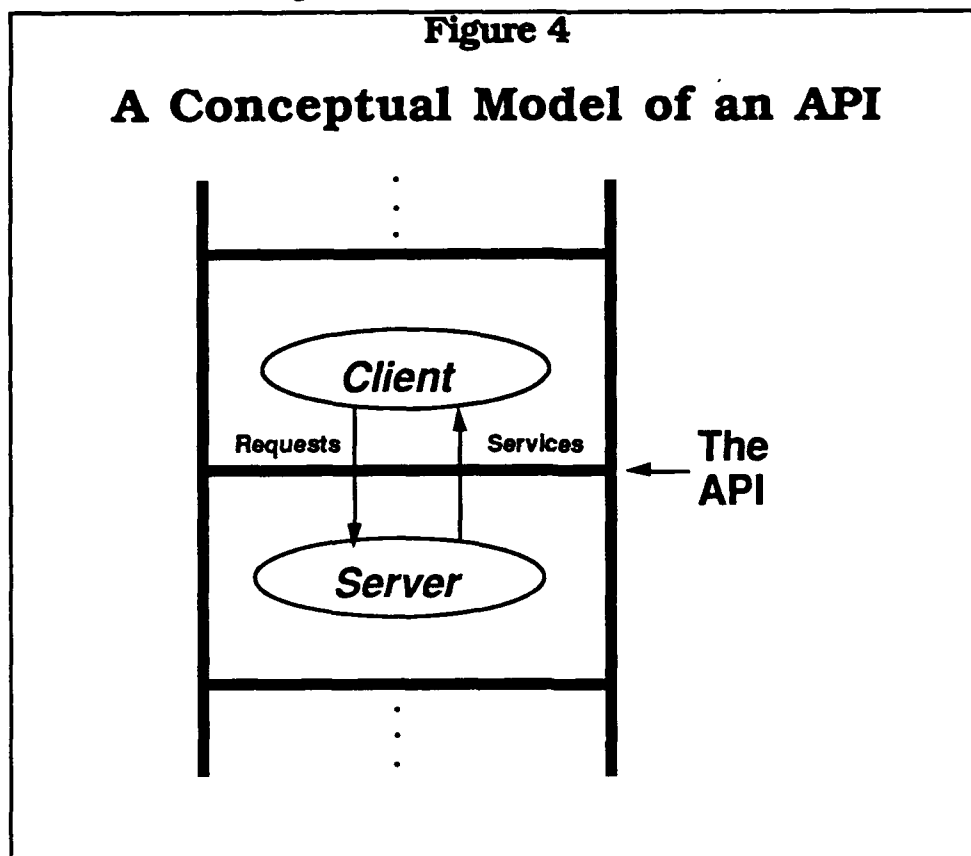
An application program interface (API) is a means to clearly divide the responsibilities and actions required in providing and utilizing a specific set of services. The standardization of an API provides the capability to develop software modules that are usable on multiple platforms with different implementations of the server module.

A typical API is an interface between two software modules — the client which accesses the services of the server. (Figure 4) The client requests services by invoking subroutines or procedure calls which the server executes. Therefore, a typical API is dependent on a particular language for its detailed definition since that would include the exact syntax (formats, etc.) of the procedure calls and replies. It should be noted that the model shown in Figure 4 can be recursive, i.e. the "client" utilizing a particular "server" may itself be a "server" for another "client."

What ISDN Applications are Missing

As the project progressed it became clear that there were a number of "applications software capabilities" that would be of high value in an ISDN environment; however, they are not yet available, or those versions that are available are not totally satisfactory.

- An Effective ISDN Call Manager
- Computer-Based Telephony
- "Groupware"
- On-Line Discussions
- Collaborative On-Line Document Preparation
- Multimedia Applications



System Response to Error Conditions

What is being referred to here is a functional error not a transmission error such as caused by noise. An example will clarify the difference.

What happens if two TEIs (ISDN terminals) are assigned the same TEI (terminal equipment identifier), perhaps by switch settings or configuration parameters, and then attached to the same S-Bus. When this was done it was observed that the CO switch removed the line from service and performed local line diagnostics for about fifteen minutes before reinstating service on this line. It was also observed that connecting two devices to a single BRI with two different TEIs can be unpredictable as one may not be recognized if added much after the first one is connected. Neither one of these has yet been rigorously tested.

Use of Multiple B-Channels

The PictureTel video conferencing equipment demonstrated another factor in using ISDN which is different from standard POTS. The provision of multiple B channels over a single copper line leads one to believe that using both of these B channels to double the effective bandwidth should be easy. This is not the case. There is no guarantee from service providers that the B channels will take the same path

through the network and so may have different delays end to end. PictureTel has solved this problem by inserting delay into their system which allows resynchronizing the B channels at the destination, but with the cost of having a noticeable delay in conversations held over their systems. The system still performs very well but this added problem needs to be solved in the future.

LAN-to-ISDN Bridging

The need to study and experiment with LAN-to-ISDN bridging capability was identified within the statement of work and the task plan for this contract. There are two aspects to the LAN/ISDN bridging problem. One was to identify existing or newly marketed equipment that was available that would provide connectivity between stations on the ISDN and stations on other LAN technologies. Another was to address some of the problems that exist in connecting standard LAN technology over ISDN. Both of these have been examined to some extent and are discussed below.

Existing equipment was of two types: that which treats ISDN as just another leased line providing 56k or 64k bits per second connectivity, and that which utilizes the dial up capability of ISDN to provide dynamic bandwidth increases to a connection between LANS. There are several bridge manufacturers who are currently providing the first, Vitalink and others, by exchanging the standard 56k data set for an ISDN external terminal adapter. This essentially requires no change to the existing equipment and will work as well or better than the previous technology. The second type of equipment is just beginning to appear. There is apparently only one manufacturer claiming to provide dynamic bandwidth allocation for bridging by using multiple ISDN channels: Teleos. Teleos, in conjunction with IBM is now offering the ability to connect IBM token ring networks together using their ASK platform with new software and a token ring VME bus card. Their claim is that as more bandwidth is needed for traffic between the two token ring networks, it is provided via other ISDN channels. As the need disappears, it is torn down. Performance data for this system is not yet available. The term "Just in Time" networking is used to describe this process, the term being taken from the manufacturing concept where parts are delivered "just in time" to be used by manufacturing.

It was felt that there were certain problems that must be solved before the complete integration of ISDN into the LAN environment could be considered complete. The Internet is considered the most functional interconnection of LANs in the world and thus was used as a model of what real interconnection should be. The example is that distributed services should run on the network and be accessible to all LANs: e.g. name service and internet mail delivery. This is not currently possible using ISDN as a LAN interconnection means, at least not in the general sense. Work is being done to more fully identify the issues involved and scope out some possible solutions. For this reason a co-project

was begun to build an ISDN adapter interface card for the NeXT computer at the College of Computing of GIT. This computer provides a UNIX platform which provides applications interfacing to the existing Internet services. The NeXT platform also provides an impressive user interface builder which allows next to no time to be dedicated to writing code for this purpose. The computer's high speed also makes it suitable for an ISDN to ethernet router in keeping with the Internet style of connection. The hardware development for this task is nearing completion and software design has begun.

Quantitative Testing

The usability of any data communications service is the result of the combination of functional capabilities provided and quantitative performance provided. The observation and evaluation of the former is relatively easy — "Does the system do 'X-Y-Z' under all conditions?" On the other hand, quantitative performance testing presents a number of problems and challenges. The most common problem encountered, not just with the ISDN services, is the lack of tools to assist in making these measurements. In this project this was addressed by a specific task to develop instrumentation for the experimental. This task was discussed above.

Initial Plans for Quantitative Testing

It was recognized early in the project that a number of quantitative tests would be required in a complete study of the ISDN-user interface services. Some of these are listed below.

- Tests of call setup time on the ISDN CO switch.
- Tests of the CO ISDN packet handler
- Tests of D channel data carrying ability
- Measurement of delay on D and B channel packet data
- Error injection into BRI service to test CO switch and packet handler

Performance Testing in the ISDN Environment

The testing facility was utilized to conduct performance testing on the ISDN. There were several tests that were attempted; however, valid results were obtained from only one set of tests.

General

The ISDN B and D channels provide basically three modes of information exchange: packet information exchange over the D channel using an asynchronous PAD function provided by an external adapter, packet information exchange over a B channel between an adapter on the ISDN line and the packet handler/packet switch in the

Central office, and synchronous, bit-oriented data over a circuit-switched B channel.

It is obvious that the synchronous, bit-oriented data over the B channel circuit should perform exactly as a modem since there is buffering in the circuit. The only results possible from this testing would be the single delay value that all data would incur as it traveled to the central office and back. It is expected that this delay value would be small although it was not tested in this project. In general, modems add delay in the neighborhood of 12 to 20 milliseconds for local calls with increasing delay related to the distance between the modems. This same or lower expectations should apply for the B channel circuit-switched service.

Performance Testing Procedures

B-channel packet switching was not tested since equipment was not available which would complete a packet call to the packet switch in the central office. B-packet lines were available; however, the available equipment (Infotron, provided by Southern Bell) was never brought into proper operation to achieve packet connections to other packet lines in the lab.

D-channel packet switching was tested and consistent results were obtained. The D channel operates in the packet mode for everything. Control packets are exchanged for call setup and idle circuit management. The D channel is multiplexed between all eight possible stations on the passive bus. This implies that the D channel is statistically multiplexed. Our past experience with statistically multiplexed systems has shown that statistical multiplexing causes random delays around some mean delay time. The smallest time is usually fixed; however, the maximum delays depend on loading into the system. These characteristics were confirmed by our testing of the ISDN D channel in the lab.

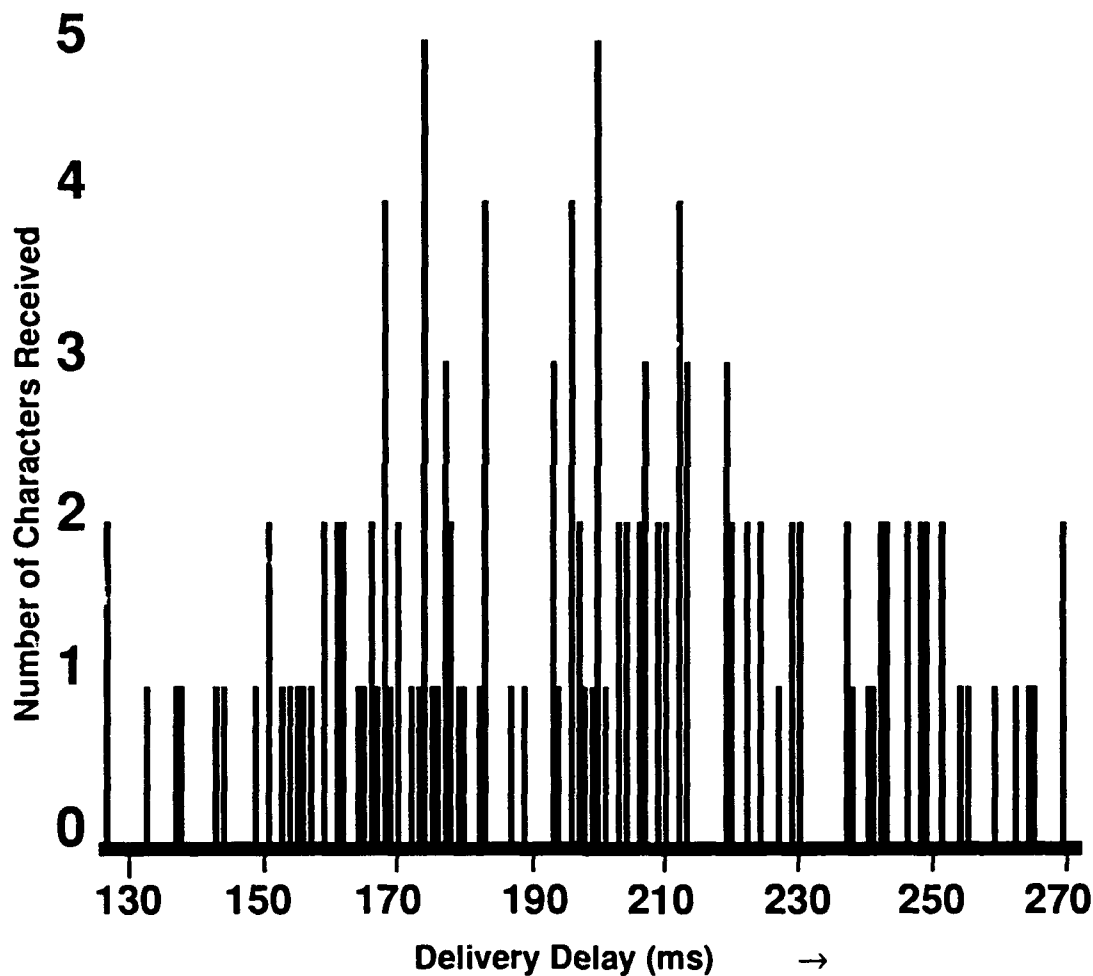
Performance Testing Results

Figure 5 is typical of the results obtained from injecting asynchronous character traffic into a D channel PAD (packet assembler disassembler) produced by Infotron. This device is a stand alone ISDN Terminal Adapter which operates in the PAD mode on the D channel and B channels. It has two ports of which one was used on each end. The character timer described elsewhere in this document was connected with its output side to one Infotron PAD and its input to the other. The circuit was set up externally and the experiments were begun using different character loading rates for different trials. The PADs were set up as follows: each character caused a single packet to be assembled and transmitted, echo was turned off, flow control was disabled, the window was left at the default value of 2 at the link level.

It must be kept in mind that the PAD function utilizes X.25 which is a

Figure 5

Character Delivery Delays
Typical Test Results — Single Test
ISDN Central Office Packet Handler
Loading: 100ms Inter-Character Delay



layered protocol and the concatenation of the link layer (LAP/D) and the packet layer (PLP) can cause some of the effects that were observed. But, in general, the observations show that the asynchronous nature of the packet handler is the main cause of the variations in delay across the network.

The graph has two axes: the horizontal axis is time delay experienced by characters as they traverse the circuit through the system under test and the vertical axis is the number of characters which incurred the delay value represented on the horizontal axis. Thus where a normal curve is shown, most characters incurred the mean delay with some coming earlier and some coming later. Interestingly, the performance measurements on the D channel usually produced bimodal graphs indicating that several different factors were overlapping causing the delays. As loading was increased, the mean of the curves always moved to the right indicating a longer delay. This can be explained by the nature of queueing systems where characters and packets are held in buffers in queues until such time as they can be transmitted. This increases the delay across the system. Since all curves were very similar, a single graph is reproduced here.

Limitations of the Experimental Setup

Equipment delay must be noted as a major cause of the large delays indicated on Figure 5. A test was done to determine the delay between sending characters into a PAD and getting the echo back. The results show that 20-40 ms. of the delay are caused by internal processing in the pad. There was no flow control available on the character timer. Thus at high character loading, the delay results could not be assumed to be accurate. The ISDN protocol analyzer connected to the line was observed for consistency of the results; and when the character timer appeared to be dropping too many characters, the results were discarded. It was consistently observed that the minimum delay incurred by characters traversing the ISDN D channel was about 130 ms. This is high compared to other packet switching systems; however, a complete test has not been done to see how this really compares to other available systems.

Performance Testing Completed

Several performance tests were performed before this phase of the project terminated.

B-Channel Call Completion

Call completion for calls local to one CO switch is very quick, less than one second. For non local calls this increases to from 5 to 30 seconds now. This is expected to decrease when SS7 is available between CO switches.

B-Channel Data Delivery-Delay

The B channel circuit, as expected, has no variability in delay. Only local CO testing has been performed.

D-Channel Data

D channel data was implemented and tested; however, this capability was not tested with the full passive bus configuration nor with heavy call setup load and heavy data loading. See Figure 5 for an example of the results of a D-Channel test.

7. Other Factors Affecting the Usability of ISDN Services

Deployment of ISDN in the United States

The deployment of ISDN Services within the United States presents several challenges and several economic as well as legal obstacles. A major problem is funding this deployment considering both new capital costs — major changes to central office hardware and software, changes to the customer distribution subsystems, and changes to the customer equipment — as well as the increases in recurring maintenance and support costs. How much more will the customer be willing to pay for the "added benefits of ISDN service"?

Even after the funding questions have been resolved another major problem still remains — what is a suitable deployment plan? Obviously, the entire country can not convert to ISDN overnight. What phasing makes sense?

Effects of "Non-Universal" Deployment of ISDN Services

Of what value are ISDN services if they are available only at your location and not at the "distant end"? Obviously, they can not be used directly. There have been proposals for the introduction of modem pools at non-ISDN central offices to handle the last mile of the data transmission; however, the implementation of such a plan would require a large amount of nationwide coordination and cooperation. There are no simple answers to this problem.

The comment has been made that the ISDN services could at least provide additional capabilities in your local area. The weakness in this argument is that operations at the "ISDN-end" would then have to support two modes of data communications operations — ISDN and non-ISDN. This, of itself, would probably be counter-productive.

There is no question that ISDN services will not become truly useful until there is reasonably widespread deployment.

Deployment of CCITT Signaling System #7 vs Deployment of ISDN

To date, almost all of the ISDN implementations have been standalone islands with no interconnections between remote locations. Part of the reason is that the local exchange and long distance central office switches have not been totally digitized. Besides this, the telcos central offices have not implemented Signaling System 7 (SS7) which is required in order to support ISDN applications between remote locations. SS7 is the key element required for ISDN universal availability which will not be totally implemented for many years. Therefore, ISDN will develop in a piecemeal manner with major metropolitan areas first having ISDN and SS7 capabilities with other remote areas eventually implementing SS7. Users will therefore increase their ISDN applications in a step-by-step basis until SS7 is

widely available to provide universal ISDN services to connect the existing islands of ISDN together.

The stumbling block in SS7 connectivity is the enormous capital expense associated with implementing the equipment for SS7 at the telco's central offices. In addition, the interconnection between local exchange companies and inter-exchange companies is taking place very slowly. While competing inter-exchange carriers have managed to interconnect SS7 networks, inter-connectivity between inter-exchange and local exchange carriers remains an elusive goal. This connectivity at the access tandem level will potentially not occur until the 1992 time frame. At the central office level, nationwide inter-connectivity probably will not be completed until the end of this century. The local exchange carriers lack the incentive to install SS7 and provide connectivity to inter-exchange carriers. In addition, the local exchange carriers are keeping inter-exchange carriers in the dark regarding local exchange interconnection plans, proposed tariff formats, rates and schedules.

The ISDN Customer Premises Equipment (CPE) Issues

The issue here is the cost of ISDN terminating equipment. It will certainly be appreciably higher than present terminating equipment — both voice and data. If the deployment is good, then businesses would probably be willing to pay the added costs for the benefits achievable. However, it is certainly doubtful that even a substantial proportion of residential subscribers would be willing to buy new, more expensive telephones to replace those that they were only recently forced to purchase. A major impact of this would be the effect on deployment plans. How can a deployment plan work that is based only on business adoptions?

The Narrowband-ISDN vs. Broadband-ISDN Controversy

Narrowband-ISDN is the basic 2B+D service — two circuit-switched channels at 64 Kbps each and one control/data channel at 16 Kbps. The perception is that there is little that the general subscriber, e.g., a residential user, can get with this that can not be obtained with the currently available services. Hence, there is little incentive to pay the added costs of new terminal equipment and increased monthly charges. Many feel that this situation will present a major, if not complete, barrier to the deployment of N-ISDN.

The availability of broadband services (above 64-Kbps, even up to Mbps) would make it possible to delivery to the general customer something that he is probably willing to pay extra for — for example, entertainment in the form of on-demand video. For this, and other reasons, many have taken the strong position that ISDN deployment in the U.S. must wait on B-ISDN to be effective.

Legal Issues Effecting The Deployment of ISDN

Legal issues will certainly have an impact on the deployment of ISDN. In Europe the public carriers are rapidly moving ahead on the deployment of ISDN for they see ISDN as an opportunity to enter into whole new areas of business — the providing of telematic services, data base access, information services, video, etc., as contrasted to strictly telecommunication services. It is the added income from the new services that will provide a large proportion of the added costs of ISDN. Of course, in the U.S. the common carriers are currently prohibited from engaging in such business.

Another legal issue has been raised that may impact some of the new services being proposed for ISDN. The particular service currently being examined is ANI-Automatic Number Identification, and the legal questions being raised have to do with privacy issues. That service is already being provided in pre-ISDN systems, and that is the cause of the present concern. The ISDN issue is that several businesses see the availability of ANI as an extremely attractive feature for improving the performance of handling customer calls. If legal restrictions are placed on ANI, that will be just one more impediment to establishing a solid business case supporting deployment.

Full Implementation of the ISDN Packet Handler

This is certainly a change in the nature of the issue being raised. This is a technical issue rather than economic or legal. There is not yet available a complete implementation of the ISDN central office packet handler. There are both implementation problems as well as specification issues that must be addressed.

The ISDN CO packet handler is almost a complete store-and-forward packet switch, and that characteristic alone defines a rather major implementation task. In fact, the packet handler has to perform a number of functions that a regular packet switch does not; and those added requirements only exacerbate the implementation problem.

A further issue is raised by the definition of the role(s) of the ISDN Packet Handler. Will it handle packet data on the D-Channel only or will it support a direct connection to a B-Channel for the purpose of handling packet data on that channel? Is the packet handler going to serve merely as a gateway into already existing packet-switched public data networks or will it also serve as a member of a new packet switched subnetwork consisting of several ISDN Packet Handlers directly trunked together? To assume the later role means that the Packet Handler becomes even more complex than a regular packet switch.

Transition to and Integration of ISDN Services

The deployment issues raised above were primarily economic ones. Again, there are definitely a number of technical issues involved. Integrating ISDN services into the existing systems, interconnecting the various systems to provide reasonable services, and transitioning to all ISDN present a number of very difficult technical problems that must be solved. It is beyond the scope of this report to discuss those; however, the magnitude of the problem can be highlighted by noting the number of systems that must be integrated.

Integrating Interexchange Carriers and Local ISDN Services and Facilities

Integrating ISDN Packet Handling with the Public Switched Telephone Networks (PSTNs)

Integrating ISDN Packet Handling with the Packet-Switched, Public Data Networks (PSPDNs)

Integrating ISDN Data Services with the Internet

Integrating ISDN Services with Private Networks

Creating an apparently "seamless network" for voice Services

Creating an apparently "seamless network" for data Services

Network Numbering Plans

Some of the details of the various numbering plans are given in the Appendix A. Suffice it to say in this paragraph that there are different numbering plans defined for the present public switched telephone networks (PSTN), the present public data networks (X.25 and X.21), and the ISDN. The maximum length of the address number is different in each plan, i.e., 12, 14, and 15 digits. The problem for the future is that all of the existing systems have to transition to the ISDN numbering plan. How to accomplish this is a major question being examined by the CCITT. (It should be noted that we often do not give numbering plans the attention they deserve and require during the planning stage to avoid the problems that can appear later.)

Network Management of "ISDN" Private Networks

Network management is an aspect of ISDN that is not well understood at this time. The understanding of what the term network management means to ISDN requires determination of the network management requirements of ISDN, both as an independent management domain and in relation to integration of an ISDN with other network technologies and management domains. Efforts towards identifying and understanding these requirements are taking place under the North American ISDN User's (NIU) Forum. There is

an ISDN Implementor's Workshop (IIW) profile team focused on Network Management and ISDN Administration. Their work is not complete at this time.

Costs of ISDN Services

How are the costs for ISDN services to be calculated? Even if the basic principle of "return on investment" (ROI) is accepted, and it generally is, the problem is allocation of the investment costs. In today's public networks the degree of integration already present creates a very difficult cost allocation problem. For the level of integration that is envisioned for ISDN, the issue of cost allocation becomes that much more difficult. The criticality of this can be appreciated when it is realized that "cost" should provide some basis for the tariff.

Effects of the "Advanced Intelligent Network" (AIN)

ISDN is basically a user interface to the services of the public networks. AIN is concerned with the internal control and operation of those public networks to provide the services. Certainly AIN will provide essential support to ISDN; however, the reverse is not necessarily true. The telephone companies are moving ahead with AIN somewhat independent of progress on ISDN, for the need for "Intelligent 800 Service" already exists and operations must be improved regardless of ISDN.

ISDN Networking Systems Design

There is no question that the availability of ISDN services will provide an opportunity for new design concepts. Many of the ideas presented for "improved" systems merely exploit the high-speed data capabilities of 64-Kbps. A few have managed to utilize the capability for simultaneous voice and data provided by the two B-Channels; however, even that can be done today with two lines. A "true ISDN" application system design would be one that supported an application in a manner that can not be done with a combination of current services. An example of such a system design is discussed below.

Customer Call Handling Using Specialized ISDN Services

When a customer call is received it is connected to an automated voice response unit that then interrogates the caller to determine some basic information such as caller ID/membership number, caller location, general nature of call, etc. This information is then placed into a data packet that is distributed to the attendant stations over their D-Channels utilizing the ISDN Packet Handler. The caller's information packet is identified by the caller's number which is provided by ANI. When the call is answered by a human attendant,

ANI again identifies the caller and permits access to the information packet which has been sent to the attendant station.

8. Summary

Objectives and Goals of This Project

The primary objective of this research and study project was to examine the applicability and usability of ISDN for a variety of present and future distributed, user applications. The approach taken was not just a simple trial usage test. In order to make the findings and results as widely applicable as possible, the approach taken was to study the detailed nature of the services provided at the ISDN user interfaces and compare these to the requirements of user applications as they could best be determined. The study goals also included a detailed study of the ISDN user interfaces to include the effects of noise and other impediments on the interface examining both the "specifications" for the interface as well as for specific implementations, the presence of improperly configured terminal equipment, and other anomalies that might be encountered in a general user environment.

Project Accomplishments

Establishment of the ISDN Experimental Facility

The first and most critical activity of the project was the establishment of the ISDN Experimental Facility. This was required to provide the test environment to accomplish the study tasks. This facility was established, although not to the extent that was originally envisioned. ISDN terminal equipment (i.e., ISDN telephones and ISDN Terminal Adapter Cards for personal computers) was obtained and installed; two ISDN central office switch simulators were installed; ten real ISDN lines were installed by the local telephone company; a limited amount of ISDN test equipment was obtained; and some ISDN application software was obtained and installed on the personal computers. Existing test equipment, i.e., a character load generator and delivery delay timer was also made available for use in the experimental facility in order to perform the initial performance measurements. A number of technical and equipment availability problems were encountered during the establishment of this facility. Although these had an adverse effect on delaying and limiting the test program, the nature and extent of these problems are considered part of the findings of this study since they would certainly have a major impact on the installation and utilization of ISDN applications by a general user.

The Testing Program

As mentioned above, the problems in establishing the test facility and the resulting delays had a major impact on the testing program. The ability to perform throughput and delivery delay tests of ISDN data

packets through real ISDN central office switches was demonstrated and initial results obtained. A large amount of additional testing must be performed before these results can be generalized. The testing of the reaction of the interface protocols to the presence of noise was not performed due to the problems encountered in designing and implementing the S-Bus Noise Injector. (Work continues under another project on the development of this piece of test equipment since testing the ISDN D-Channel protocols in the presence of noise is considered an important aspect of our overall ISDN research program.)

Factors Effecting the Use of ISDN

Availability of ISDN Applications

One of the major impediments to the acceptance and utilization of ISDN communication services at the present time is the almost total absence of ISDN applications. Of course this can be a "Catch-22" or a "chicken and egg" situation — there are no ISDN applications available because there is no market for them and there is no market because there are no applications to generate the market interest. Obviously, if widespread utilization of ISDN services is to occur, something must break this circular deadlock.

Another factor that is affecting the preparation of ISDN applications is the lack of a standard ISDN API (Application Program Interface) to create an environment in which ISDN applications could, at least to some degree, be portable across different execution platforms. The development of a "standard" ISDN API(s) appears to be a key factor in fostering the growth of usage in this area, and this issue is being addressed by a working group within the North American ISDN User Group (NIU).

Availability of ISDN Services

A communication service is of little or no value if it is not available to provide end-to-end service. It is difficult to generate interest in ISDN services when they are being provided only in widely separated geographical islands, and it is not at all clear to potential users when the amount of geographical coverage will be improved to the level necessary to make the services attractive or even usable.

Market Perception of ISDN

Another significant factor that affects the acceptance and utilization of ISDN services was observed during this study. ISDN has for the most part been "marketed" as a technology not as services. Users are reacting as might be expected in wondering why they should be interested in a new technology when what they want are services.

Cost of ISDN Services

There is no question that an ISDN access line to a central office will cost more than a "plain old telephone" (POTS) line. The increases in costs will not only affect the access line charges themselves but also the cost of terminal equipment. Statements are made by some telephone company executives that they are "willing to pay 1.5 times as much per line for an ISDN central office as compared to a standard switch." These added costs must be recovered from somewhere, and the only logical answer is increased subscriber charges. Although major reductions can be anticipated in the costs of ISDN terminal equipment, those devices will still cost appreciable more than regular telephones and modems, and the users do not perceive any really important improvements in the services that they obtain.

Network Management and ISDN

Another factor that is going to have a strong effect on the use of ISDN is the availability of network management capabilities for utilization with ISDN services, especially when those services are being utilized as resources in a private data network. Network management is being more and more important to network operators, and for ISDN services to be effectively and widely utilized it must be supported.

Other Findings of the Project**Complexity of Service Offering**

Although the ISDN user services are not very complex conceptually, i.e., digital access to a variety of communication services, in practice they are. The complexity is first encountered when the initial order is placed for ISDN service — the customer must specify the options and features desired and some technical details; matters that never concerned him before. In addition, the use of the services and the detection and handling of troubles presents additional technical issues to the users that they are not prepared to deal with.

ISDN Development Problems

Any new technology is going to have its share of development problems; however, the development and implementation of ISDN, which really equates to the implementation of the ISDN Central Office, seems to have had a large number of delays. This may well be the result of the problems in developing packet handling capabilities; however, these should certainly have been anticipated by anyone who is at all familiar with the development of similar capabilities in standalone packet switches.

Effects of Standards

Although the important standards for ISDN interfaces were published in 1984 and developed even earlier, there were still a number of open issues that required standardization — network termination interfaces, testing, control messages, and many others. There is no doubt that the absence of these standards has had an adverse effect on the development of ISDN equipment as well as its acceptance, even in concept, by knowledgeable user communities.

What Might be the Real Value of ISDN

The above comments may paint too bleak a picture for the value of ISDN services. That is really not a valid assessment of the situation. There are a number of problems that must be overcome in order to achieve major user acceptance, availability of ISDN applications, simplification of usage, and widespread deployment; however, ISDN services do have something valuable to offer the users.

Support for "Unique" Applications

There are applications that can only be implemented using integrated, high-speed services such as those available with ISDN. One of those was examined by the research team in another project, and the value of using ISDN was quite obvious.

Public Switched Digital Service

ISDN services will provide a capability heretofore not available in the United States, switched digital service. However, even in this area that has previously been left unserved, competition to ISDN is arising with the SMDS service offering which is now beginning to appear.

LAN Bridging

LAN bridging, i.e., the interconnection of private local area networks, is not well supported with the public networks services currently available. There is no question that ISDN would be extremely useful here; however, it is not clear that this usage alone is significant enough to have a major impact on the demand for ISDN.

The Future**Narrowband-ISDN (N-ISDN) vs. Broadband-ISDN (B-ISDN)**

One possible scenario for the future of ISDN is the deployment of B-ISDN in the United States rather than N-ISDN. With N-ISDN, the general user will not be able to any services that he cannot already obtain today at lower cost; not much of a marketing position to be in to pay for the deployment of a new technology. On the other hand, B-

ISDN to the home will greatly increase the service and application options to include new services such as video on demand, and there is no question that a major factor in the acceptance of a new technology that carries new costs is its entertainment value.

ISDN Will Occur

As one speaker remarked at the closing session of the 1987 conference on Evolving to the ISDN in North America, "The telephone companies are going to go to ISDN since it will save them money, the real question is whether or not the users will receive any real benefits from this." Even though what he was referring to is more properly identified as the IDN, the "Integrated Digital Network," he did make an accurate statement of direction for the public networks and raise an important question which is still unanswered.

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**Technical Issues in Evolving to
Integrated Services
Digital Networks (ISDN)**

Final Report

Appendices

**Technical Issues in Evolving to
Integrated Services
Digital Networks (ISDN)**

Appendix A
ISDN Concepts and Terminology

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ISDN Terminology and Concepts

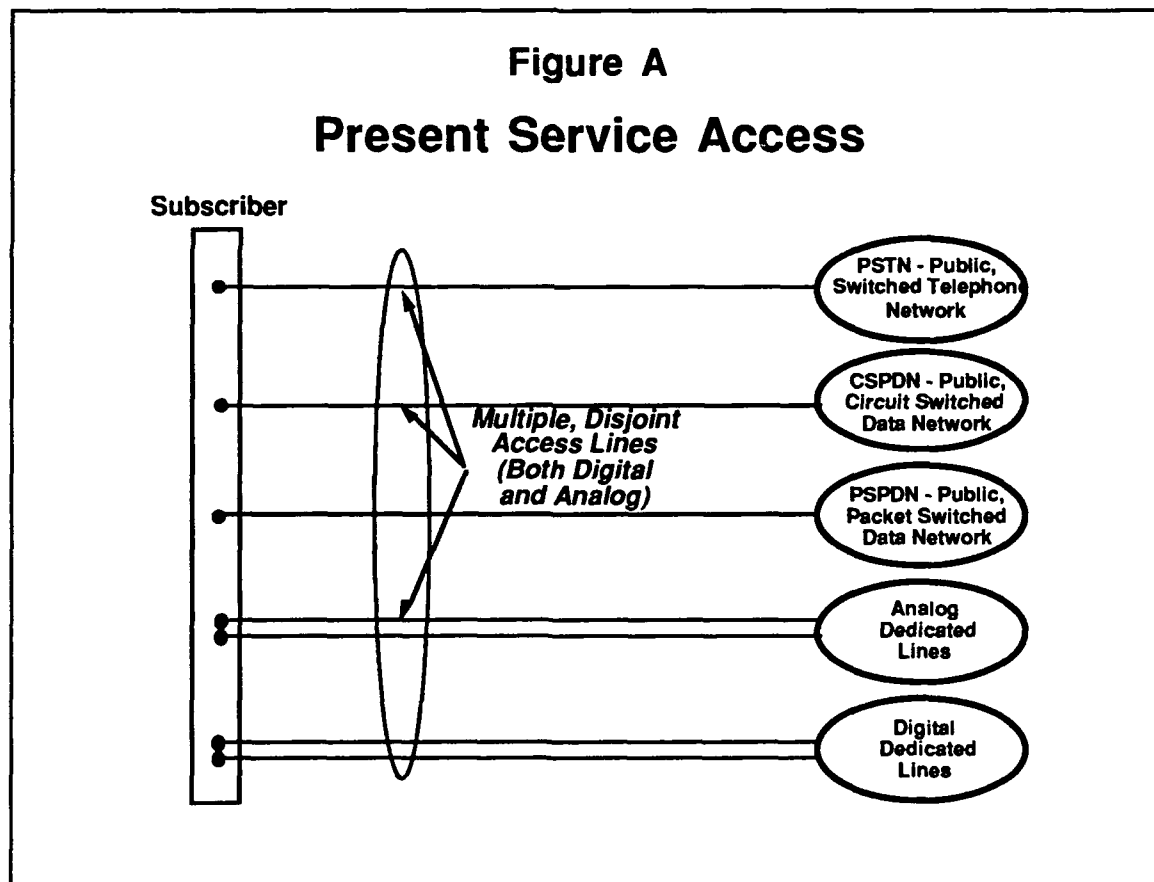
Definition of ISDN

An ISDN is a network, in general evolving from a telephone IDN (Integrated Digital Network), that provides end-to-end digital connectivity to support a wide range of services, including voice and non-voice services to which users have access by a limited set of standard, multipurpose user-network interfaces.

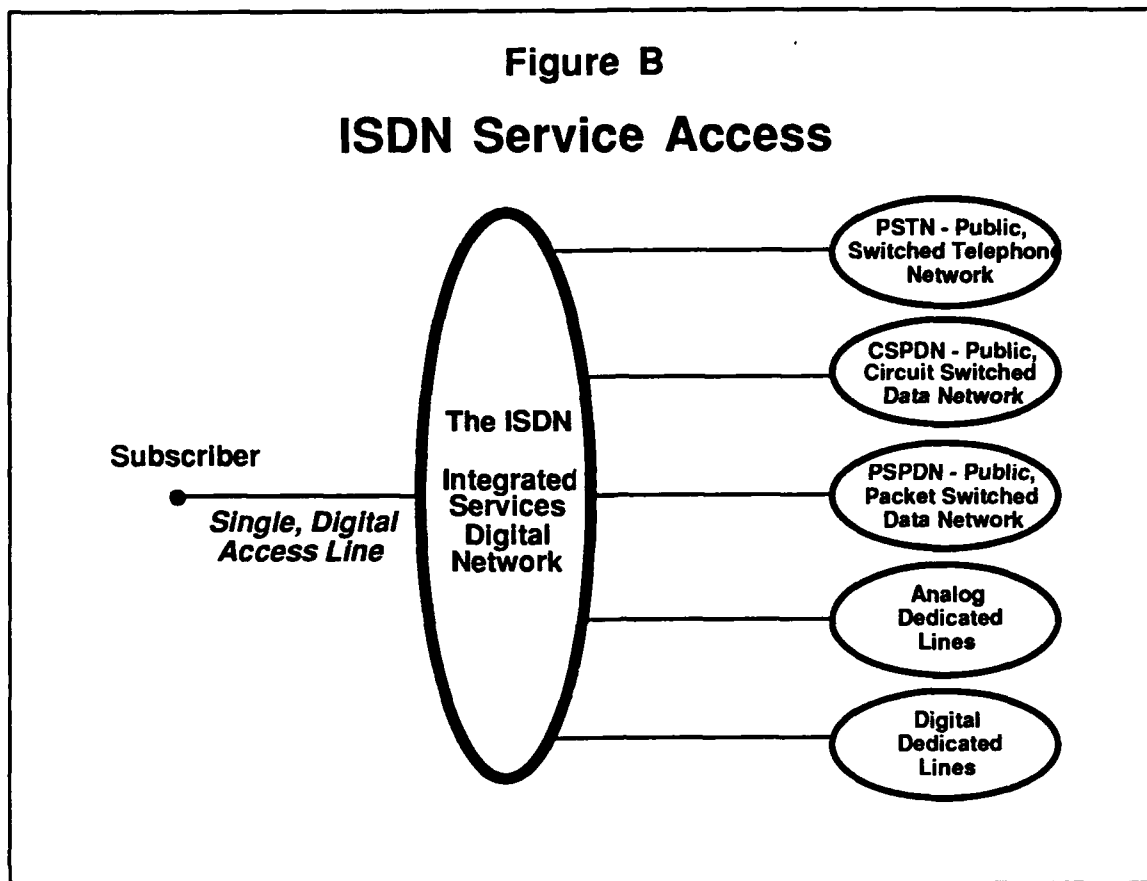
Basic Concepts of ISDN

Access

- Integrated digital access to all telecom services
- Present situation (Figure A)
 - Multiple access lines
 - Some digital, some analog



- ISDN access situation (Figure B)
 - Single access line
 - All digital



Models of the ISDN Interface

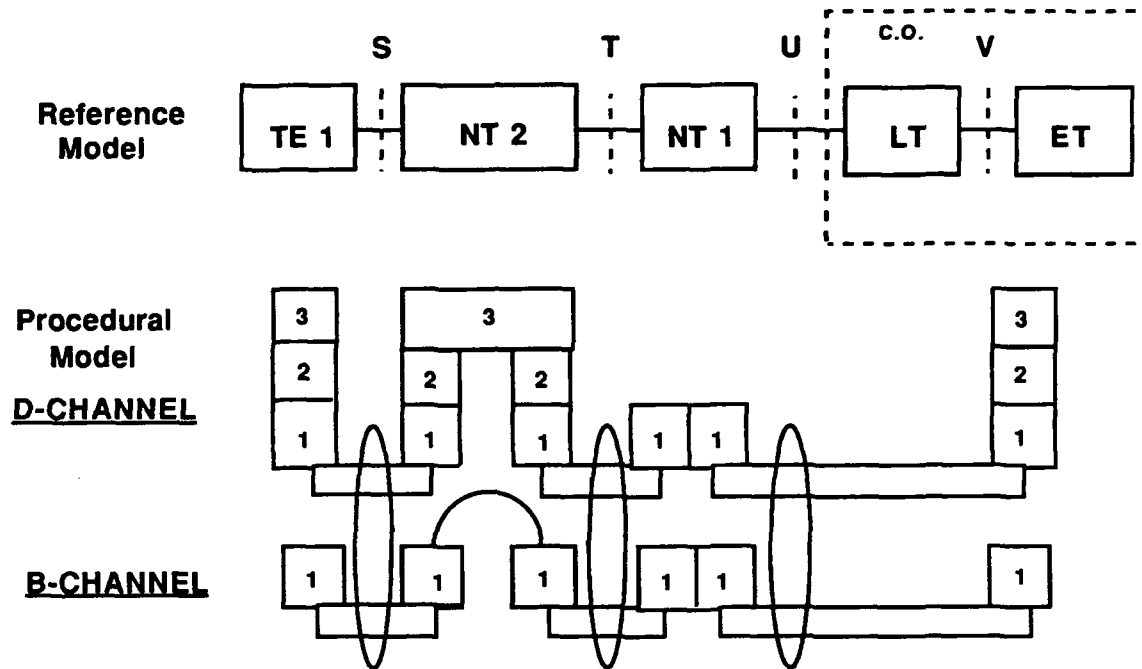
Interface Procedural Model

- Figure C
- Identifies the layers (OSI) involved in the interaction on each channel.
 - B-channel
 - Information path only
 - TE1, NT2, and NT1 perform signal conversion only
 - Signalling all done on D-channel
 - D-channel
 - Same path used for both signalling (level 3) and information transfer

Interface Reference Model

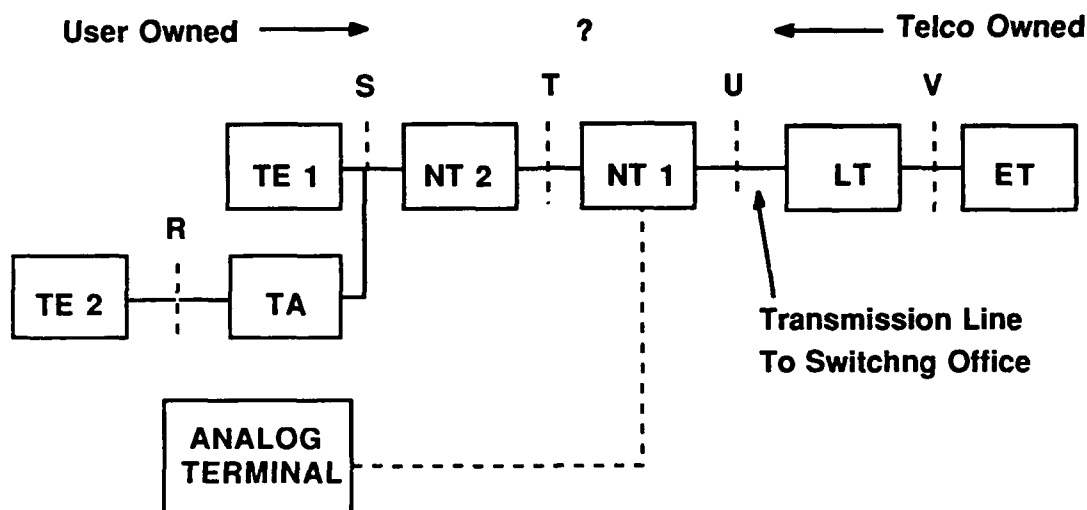
- Figure D
- Identifies equipment boxes and interfaces between them.

Figure C
Models of the ISDN User Interface



ISDN Interface Reference Points

Figure D ISDN Reference Model Interfaces



The ISDN Interfaces

Service Interfaces

Basic Rate Interface

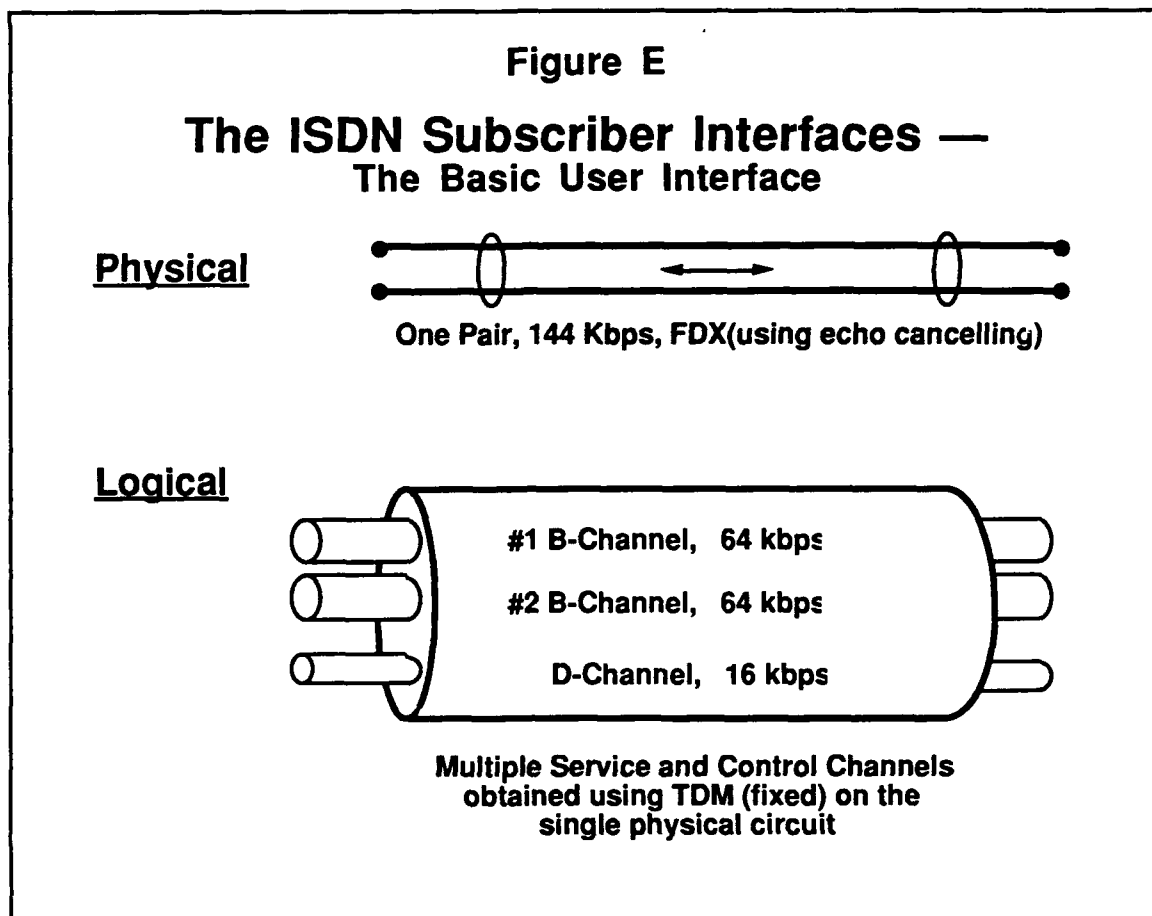
- The Basic Rate Interface, commonly referred to as the BRI, consists of two B channels (64 kbps) and one D channel (16 kbs) or 2B+D for a total of 144 kbs directly usable by the subscriber. (Figure E)

Primary Rate Interface

The Primary Rate Interface or PRI consists of 23 B channels and one 64 kbs D channel for 23B+D. It operates at 1.544 Mbs in the US and 2.048 Mbs in Europe. For both BRI and PRI, the B channel carries the user's voice, data or image information. The D channel carries signaling or packet data for the BRI interface and only signaling for PRI. (Figure F)

Primary Rate Interface

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Physical Interface Points

The R Interface

- An existing defined non-ISDN interface.

The S Interface

- A standard defined ISDN interface.
- The S interface is the interface between customer's receiving terminal and terminal equipment at customer premise.

The T Interface

- A standard defined ISDN interface.

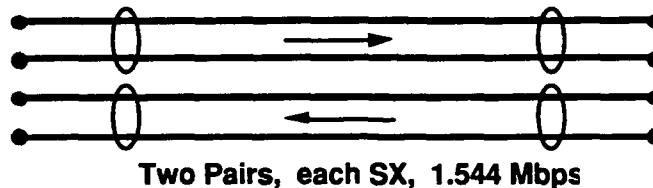
The U Interface

- **NOT** defined by CCITT - ("CONTROVERSIAL" in the USA).
- The U interface is the connection between a switch and customer which allows for full-duplexed 144 kbs.

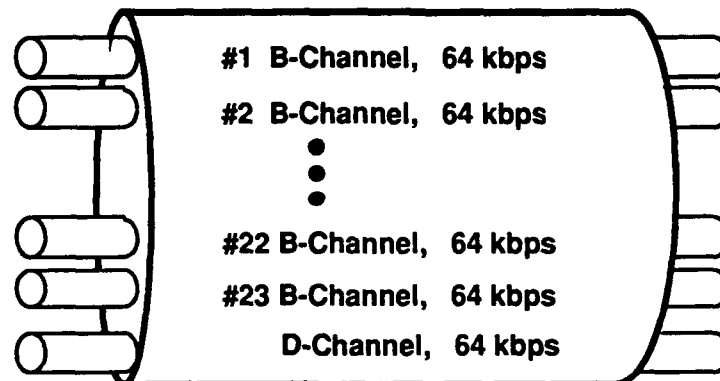
Figure F

The ISDN Subscriber Interfaces — The Primary User Interface

Physical



Logical



The V Interface

- Telco equipment interface - being defined.

Basic Rate Interface — "T" and "U" Bit Rates

- The bit rate commonly given for the Basic Rate Interface (BRI) is 144 Kbps.
 - This is the combined bit rate of the user channels —
 $2B+D, (2 \times 64) + 16 = 144 \text{ Kbps}$
 - In addition, there are framing, control, and electrical balancing bits associated with each bit stream. (Figure G)
- At the S and T reference points
 - S/T basic channels

2B channels	@	8 bits each
1D channel	@	<u>2 bits</u>
		18 bits
 - S/T Frame

2 sets of the 2B channels	32 bits
2 sets of the D channel	4 bits
framing, control, electrical balance	<u>12 bits</u>

- Frame size 48 bits
 - S/T line speed
 - 4000 frames per second
48 x 4000 = 192,000 bps
 - Line encoding
 - Pseudo ternary — 1 bit per baud
 - Line operates at 192,000 baud
 - At the U reference point
 - U basic channels

2B channels	@	8 bits each
1D channel	@	<u>2 bits</u>
		18 bits
 - U frame

12 sets of the 2B channels	192 bits
12 sets of the D channel	24 bits
framing, control, electrical balance	<u>24 bits</u>
Frame size	240 bits
 - U line speeds
 - 666.67 Frames per second
240 x 666.67 = 160,000 bps
 - Line encoding
 - 2B1Q (2 binary, 1 Quaternary)
2 bits per baud
 - Line operates at 80,000 baud

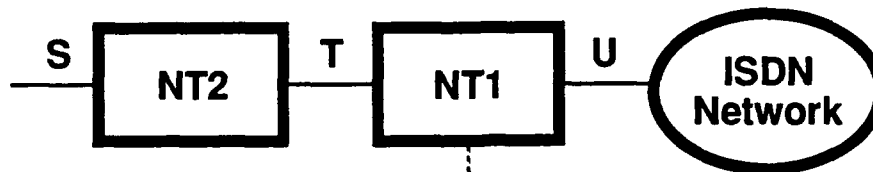
ISDN Equipment

NT – Network Termination

- NT1 - Network Termination 1
 - Broadly defined as functions belonging to layer 1 of the OSI model. Converts the characteristics of the subscriber loop to a standard ISDN interface. (Primarily a signal converter and line controller.)
 - Includes functions broadly equivalent to Layer 1 (Physical) of the OSI Reference Model.
 - These functions are associated with the proper physical and electromagnetic termination of the network.
 - NT1 functions are
 - Line Transmission Termination
 - Layer 1 Line Maintenance Functions and Performance Monitoring
 - Timing
 - Power Transfer
 - Layer 1 Multiplexing
 - Interface Termination, including Multidrop Termination employing Layer 1 Contention Resolution

Figure G

S, T, and U Basic Bit Rates

For the S and T Interfaces

At the S and T reference points

S/T basic channels

2B channels @ 8 bits each

1D channel @ 2 bits

18 bits

S/T frame

2 sets of the 2B channels 32 bits

2 sets of the D channel 4 bits

framing, control, electrical

balance 12 bitsFrame size 48 bits

S/T line speed

4000 frames per second

 $48 \times 4000 = 192,000$ bps

Line encoding

Pseudo ternary — 1 bit per baud

Line operates at 192,000 baud

For the U Interface

U basic channels

2B channels @ 8 bits each

1D channel @ 2 bits18 bits

U frame

12 sets of the 2B channels 192 bits

12 sets of the D channel 24 bits

framing, control, electrical

balance 24 bitsFrame size 240 bits

U line speed

666.67 frames per second

 $240 \times 666.67 = 160$ bps

Line encoding

2B1Q (2 binary, 1 Quaternary)

Line operates at 80,000 baud

- NT2 - Network Termination 2
 - Combines the output of several ISDN interfaces (terminals) for presentation over a single ISDN interface (e.g. PABX, key set, LAN controller).
 - Includes functions broadly equivalent to Layer 1 and higher layers of CCITT Recommendation X.200, the OSI Reference Model.
 - PABXs, Local Area Networks, and Terminal Controllers are examples of equipment or combinations of equipment that provide NT2 functions.
 - NT2 functions include
 - Layers 2 and 3 Protocol Handling
 - Layers 2 and 3 Multiplexing
 - Switching
 - Concentration
 - Maintenance Functions
 - Interface Termination and other Layer 1 Functions
- NT Examples
 - A PABX can provide NT2 functions at 1, 2 and 3.

- • Simple terminal controllers can provide NT2 functions at only Layers 2 and 2.
- • In a specific access arrangement, the NT2 functional group may consist of only physical connections.

TE - ISDN Terminal Equipment

- Includes functions broadly belonging to Layer 1 and higher layers of the X.200 OSI Reference Model.
 - • Digital telephones, data terminal equipment, and integrated workstations are examples of equipment or combinations of equipment that provide the functions.
 - • The TE functions are
 - • • Protocol handling
 - • • Maintenance functions
 - • • Interface functions
 - • • Connection functions to other equipment
- TE1 - Terminal Equipment Type 1
 - • Figure H
 - • Conforms to an ISDN standard interface.
 - • Includes functions belonging to the Functional Group TE, and with an Interface that complies with the ISDN User-Network Interface Recommendations.
 - • Multiple TE1s on a single S-Bus (Figure I)
- TE2 - Terminal Equipment Type 2
 - • Interface conforms to a standard other than ISDN.
 - • Includes functions belonging to the Functional Group TE but with an Interface that complies with Interface Recommendations other than the ISDN Interface Recommendation (e.g., the X-Series Interface Recommendations) or interfaces not included in CCITT Recommendations.

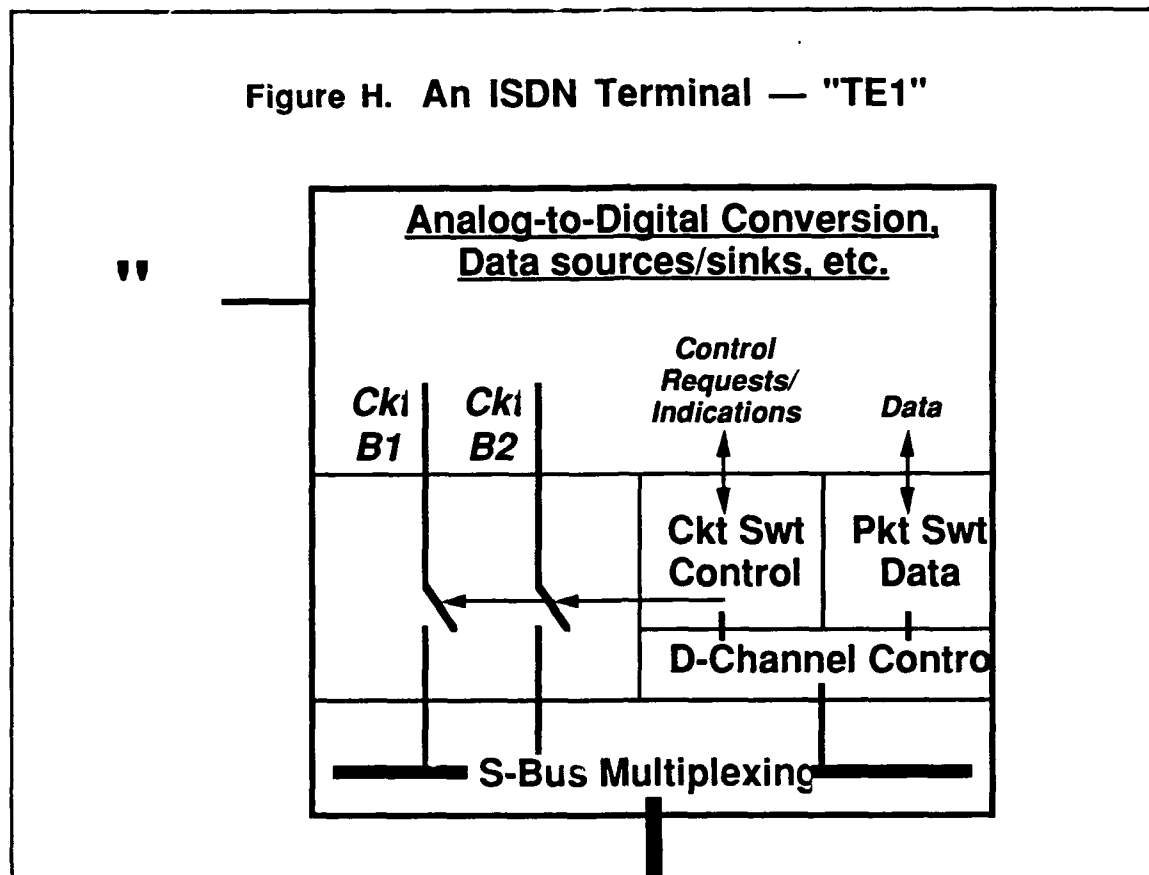
TA — ISDN Terminal Adapter

- Allows existing equipment to conform to a standard
- Includes functions broadly belonging to Layer 1 and higher layers of the OSI Reference Model that allow a TE2 Terminal to be served by an ISDN user-network interface.
- Adaptors between physical interfaces at reference points R and S or R and T are examples of equipment or combinations of equipment that provide TA Functions.

LT— Line Termination

- Provides the termination of the subscriber loop at the central office end.

Figure H. An ISDN Terminal — "TE1"



ET — Exchange Terminations

- Provides the functions required for interfacing the subscriber line to the exchange.

ISDN Services

ISDN Channel Types

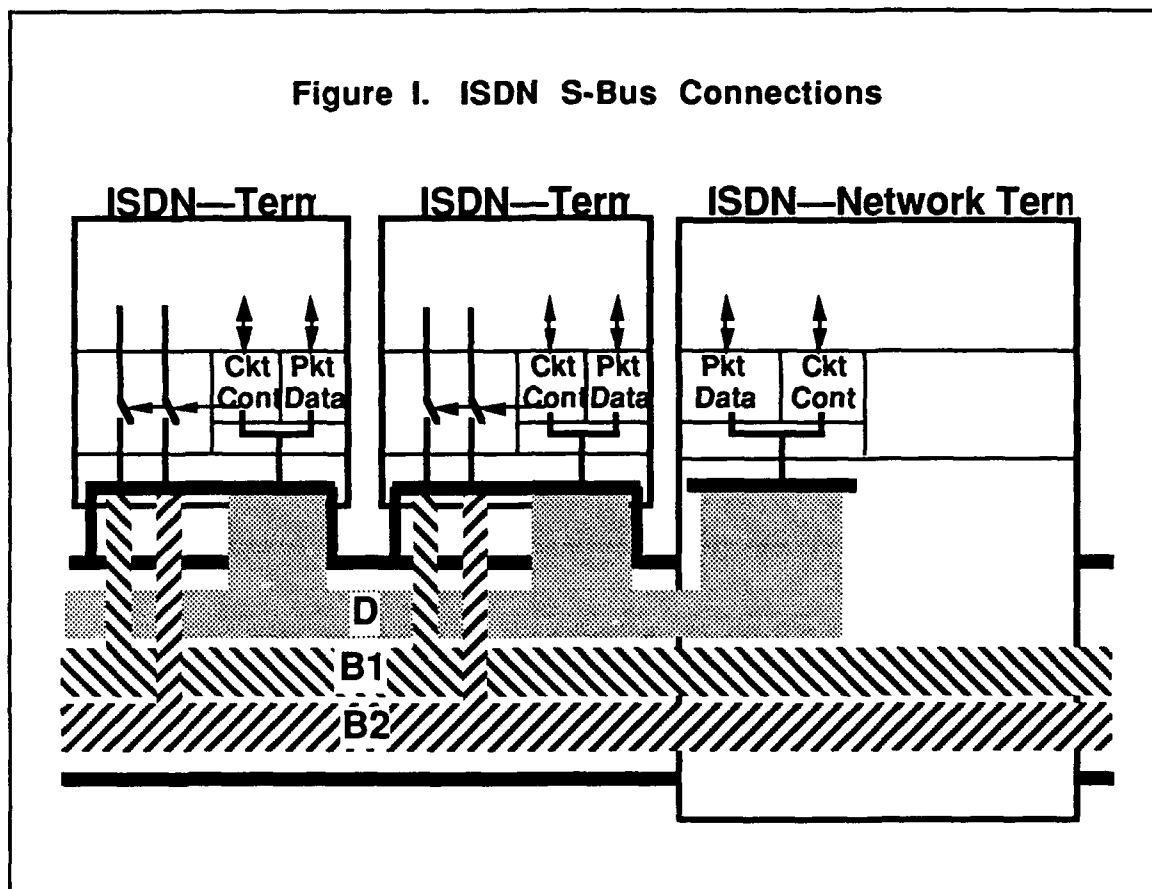
Narrowband ISDN Channels

B-Channel

- The basic ISDN Digital Information Channel
- Capacity
 - 64 KBit/s
- Signal Types
 - PCM Voice
 - Wide Band Speech (7 KHZ)
 - Image (single frames)
 - Digital Data (to 64 KBit/s)
 - Subrate Digital Data (less than 64 Kbps)

- Information Transfer Mode
 - Circuit Switched
 - Packet Switched
 - Private Line (i.e., dedicated, not switched)

Figure I. ISDN S-Bus Connections



- Signalling
 - Out-of-Band, carried separately on Associated D Channel

D-Channel

- Used for
 - Signalling
 - Switched, Packet Data Network access
- Capacity
 - 16 Kbps - for basic access, with 2 or fewer B Channels
 - 64 Kbps - for primary rate access, with more than 2 B Channels
- Signal Types
 - Signalling for B or Wideband Channels
 - Packet Type Data
 - Telemetry, etc.
- Information Transfer Mode
 - Packet Switched

- Signalling
 - In-band, within the D Channel protocol

H0-Channel

- A Broadband Digital Channel
- Capacities
 - HO - 384 KBit/s
- Signal Types
 - HO
 - High quality audio
 - Other high speed digital information
- Information Transfer Mode
 - Initially private line only

H1-Channel

- Broadband Digital Channels
- Capacities
 - H11 - 1536 KBit/s (4HO channels)
 - H12 - 1920 KBit/s (5HO channels)
- Signal Types
 - H11, H12
 - Video for teleconferencing
 - High speed digital information
- Information Transfer Mode
 - Initially private line only

Establishment of Standards

Currently, the CCITT and their ISDN study groups are responsible for the development of recommendations for international ISDN standards. The CCITT is a branch of an arm of the United Nations, the International Telecommunications Union (ITU). Most European countries are represented in the CCITT by their PTTs (Postal Telegraph and Telecommunications). The U.S. representative to the CCITT is the American National Standards Institute (ANSI) T1 Standards Committee, an organization sponsored by the Exchange Carriers Standards Association (ECSA). The T1 subcommittee focusing on ISDN is called T1D1. The T1D1 subcommittee participates in CCITT's international body related to ISDN standards and also proposed ISDN standards unique to U.S. networks pending approval by ANSI. In addition to ECSA, the Open System Interconnection (OSI) technical subcommittee is responsible for ISDN standards for the seven-layer OSI model.

North America vs. The World

U.S. standards organizations involved with ISDN standards include: the National Institute for Standards and Technology which, in the past year, formed

the North American ISDN Users Forum; Bell Communication Research (Bellcore); the Corporation for Open Systems (COS); the Electronics Industries Association (EIA); the Institute for Computer Sciences and Technology (ICST); the Institute of Electrical and Electronic Engineerings (IEEE); and the International Electrotechnical committee (IEC).

ISDN standards relate closely to the ISO seven-layer reference model for Open System Interconnection (OSI). ISDN and OSI standards are independent of each other, but the ISDN protocols were developed with the OSI framework in mind. ISDN occupies the lowest three layers of the OSI model: Physical Layer 1; Data Link Layer 2; and the Network Layer 3. OSI and ISDN are complimentary standards that, in the future, will allow different networks to interoperate.

The current standards for ISDN are the I-Series Recommendations which are summarized in this section. The I.100 Series is a comprehensive introduction to ISDN, describing fundamental ISDN principles, terminology, characterization and methods. The I.200 Series describes ISDN services including bearer services and teleservices. The I.300 Series describes network aspects of ISDN. These include network functional principles; an ISDN reference model; numbering; addressing, and routing principles; connection types; and performance objectives. The I.400 Series includes different versions of the interface between users and the network. This includes specifications for BRI and PRI. Layers 1, 2, and 3 specifications for the S and T reference points are also provided along with the procedures for adapting non-ISDN terminals to an ISDN network.

ISDN standards have moved rapidly in the past two years and are virtually completed with two notable exceptions: Q.931 signaling at Layer 3 and Q.932 special services. Most of the standards activity with regard to Q.931 is expected to be resolved by the third quarter of 1990. A recent development is the standardization of the 2B1Q line code which is specified for North America (other countries have adopted different coding techniques). A line code is the electrical representation of the digital signals, the actual "1s" and "0s" transmitted. To this pattern of pulses, 2B1Q adds adaptive digital signal processing (which smooths out interference on a line) to create the capability of using ordinary telephone twisted pair wiring for distances up to 18,000 feet.

The "U" Interface

Public Network Numbering Plans

- The CCITT has developed several numbering plans for public networks
 - E.164 — "Numbering Plan for the ISDN ERA"
 - An international numbering plan for the worldwide networking of voice and data
 - Specifies an international address less than or equal to 15 decimal digits
 - Until 31 December, 1996, the maximum length of an ISDN address is limited to 12 digits. This restriction was

- added to make the transition from the PSTN numbering plan easier (see below)
 - ... The ISDN number consists of a country code of up to 3 digits and a "nationally defined national significance number (NSN)"
- .. E.163 — "Numbering Plan for the International Telephone Service"
- .. X.121 — "International Numbering Plan for Public Data Networks"
 - ... Applicable to all public data networks (PDNs), both packet-switched and circuit-switched
 - ... An international address of 14 digits or less
 - Format 1
 - Data Country Code (DCC) - 3 digits, "ZXX" where Z = 2-7 and X = 0-9
 - National Terminal Number (NTN) - up to 11 digits, "XXXXXXXXXX"
 - Format Z
 - Data Network Identification Code (DNLC) - 4 digits, "DCC+X"
 - National Terminal Number (NTN) - up to 10 digits, "XXXXXXXXXX"
 - ... Also specifies an international prefix digit that can be defined and used by the national authorities
 - ... BellCore has defined a pseudo DNIC code of 9001 to be used for the North American ISDN field trials
- .. F.69 — "Plan for TELEX Destination Codes"
 - ... Specifies 2 or 3-digit country/region codes
- Problems — current and future
 - .. As ISDN evolves, the operation of these various numbering plans must be coordinated
 - ... "E.163 Systems" (PSTNs) must become integrated into the ISDN and adopt the E.164 numbering system
 - ... "X.121 Systems" (PDNs both packet switched and circuit-switched) must immediately internetwork with the ISDN and its numbering plan and must eventually be fully integrated into the E.164 plan.
 - .. A recent meeting of the CCITT special group on addressing identified over 50 different scenarios describing various internetworking and evolution situations.

**Technical Issues in Evolving to
Integrated Services
Digital Networks (ISDN)**

Appendix B

Study of D-Channel Protocols

Background

The doctoral research of Koo-Don Chung was originally motivated by this project and the interest in studying the access protocol for the D-Channel of the Basic Rate Interface. All of the characteristics of this protocol are of interest; however, Chung's detailed research focused on the issues of fairness and efficiency. Other characteristics such as robustness and measured performance required instrumentation capabilities in the experimental facility that were not available in time for Chung's work.

Characterizing the D-Channel and Outline of Work

Chung considered the D-Channel protocol to utilize one form of "cyclic transmission control." Quoting from his thesis, "Data Transfer over Multiplexed Logical Data Links Sharing a Single Physical Circuit," Georgia Institute of Technology, Atlanta, Georgia, 1990.

"This thesis examines the performance and the characteristics of the data transfer over a single physical circuit which is shared by multiple, logical data links. In the sharing of the communication medium, a proper transmission control (or multiplexing) scheme must be utilized. In particular, . . . cyclic transmission control schemes [are considered] in which, at most one data unit (or frame) for each logical data link user can be transmitted in each transmission cycle. This type of transmission control has been extensively studied during the last two decades. However, an exact analysis has not been derived except for some special cases.

"First, . . . an approximate analysis [is presented] for the cyclic transmission control scheme which is modeled by a number of $M/G/1$ queues served by a single server in a cyclic manner. Then, the analysis is extended for systems with $M^x/1/G/1$ queues. Extensive computer simulation results verify that the analysis yields accurate estimates of the mean waiting time and the cycle time variances for a wide range of parameters values. Comparisons with several well-known approximations are also presented.

"Next, . . . systems with multiple-priority queues [are considered]. The stability conditions for individual queues and the conservation law for each priority class are derived. An approximation formula for the mean waiting time of individual queues [is] also presented. Simulation results show that the formula yields accurate estimates of the mean waiting times when the traffic for the queues within each priority class is not very heavy and not highly asymmetric.

"Finally, . . . the effect of cyclic transmission control on window flow-control mechanism [is examined]. The properties and the performance of several alternative acknowledgement strategies are compared by means of computer simulations and worst case analyses."

Contention on the ISDN D-Channel

"[Contention] access control is implemented on the D-channel at the ISDN basic rate user interface. In this protocol, all the transmissions by the users, Terminal Equipment (TEs) in ISDN terminology, are synchronized. Each TE can read each 'bit' (0 or 1) transmitted on the channel which is echoed by the terminal controller, Network Termination (NT) in ISDN terminology, on a separate channel called the D-Echo channel. A TE is allowed to send data if it detects an idle channel, which is identified by counting a number of consecutive 1's on the D-Echo channel. Therefore, all the frames must be protected from the false indication of an idle channel which is achieved by the technique known as *bit stuffing*. Channel access priorities are defined by using different definitions of idle channel, i.e., a TE which wants to send a frame with higher priority counts a smaller number of 1's than all the TEs which have frames with lower priority. Within each priority class, round-robin priority rule is enforced as follows. If a TE successfully transmits a frame, it temporarily lowers its own priority level until the current cycle completes which is recognized by detecting an idle channel with its temporary priority. It returns to its original priority upon detection of the end of the current cycle.

"If more than one TE transmits at the same time, this situation usually occurs at the end of a frame transmission if there is more than one TE waiting for the channel to become idle, then the data transmitted on the output channel is defined as the result of a logical 'or' operation on all the bits transmitted at that time. The conflicts for channel access (or collisions) are detected at each transmitting TE by comparing each bit in the [address it transmits with the address bits echoed on the D-Channel].

"The D-channel access control protocol can now be summarized as follows (see CCITT I.430] for a complete description of the protocol). If a TE has data to send, it first determines whether or not the output channel is idle according to the history of the bits transmitted on the channel. If the channel is busy, the TE must wait until the channel becomes idle. If the channel is idle, it transmits the data according to the following procedure.

1. Let $i = 1$.
2. Transmit the i th bit in the data.
3. Read the bit transmitted on the D-echo channel.
4. If a collision is detected, then wait until the channel becomes idle and restart the transmission from the beginning.
5. If all the bits in the data are transmitted, then STOP. Otherwise, set $i = i + 1$ and then GOTO step 2.

"Figure 2.2 illustrates an example of collision resolutions within the D-channel access protocol. This protocol is collision free in a sense that there is always one TE which completes its transmission even if more than one TE starts to transmit at the same time. The transmission cycle time can now be expressed as

$$T^c = \sum_{i \in SU} (T^I + T^d_i) \quad (2.4)$$

Where T^I denote the time required by each TE to detect an idle channel.

"Note that the transmission cycle times in (2.3) and (2.4) may be considered as polling cycle times without switchover times by including the scheduling overheads, T^0_i or T^I , into the data transmission times T or T^0_i or all i . For this reason, we will refer to the transmission schemes in which the transmission cycle times can be expressed in the form of (2.4), i.e., T^c is not affected by the users not sending data in that cycle, as cyclic transmission control schemes *without* or *zero* switchover times. Figure 2.3 shows the differences in the cyclic transmission control schemes presented above.

Motivation for Analytic Approach Taken in this Research

"The basic underlying motivation for the approach taken here is a goal to develop an analytical model suitable for analyzing the performance of the ISDN D-channel. When the operation of the D-channel access protocol is analyzed, it is seen that the D-channel operation can be modeled as a cyclic service system with zero switchover times."

Some of Chung's findings were:

"The multiplexing effect in multiplexed logical data links was examined. It was observed that the acknowledgement delay in LAPD protocol increases as the number of logical data links increases. This makes it difficult to determine link parameter values, window size, and timeout intervals, especially when the number of active logical data link is large or changing dynamically over time.

"[S]ome alternative approaches [are presented] as remedies to the multiplexing effect. NOPIG [no piggyback acknowledgements] shows better performance than . . . LAPD in the average; however, [it] may not be acceptable in some applications because of the starvation problem. The stand-alone acknowledgement strategy with priority [Rei79] works the same as NOPIG at the user-network interface.

"With PRACK [priority acknowledgements] and/or SEPEF [separation of error control and flow control], the average performance can be improved significantly over the LAPD protocol. The multiplexing effect on acknowledgement delay in both PRACK and SEPEF is shown to be bounded by a constant time. This property is very important because the parameter

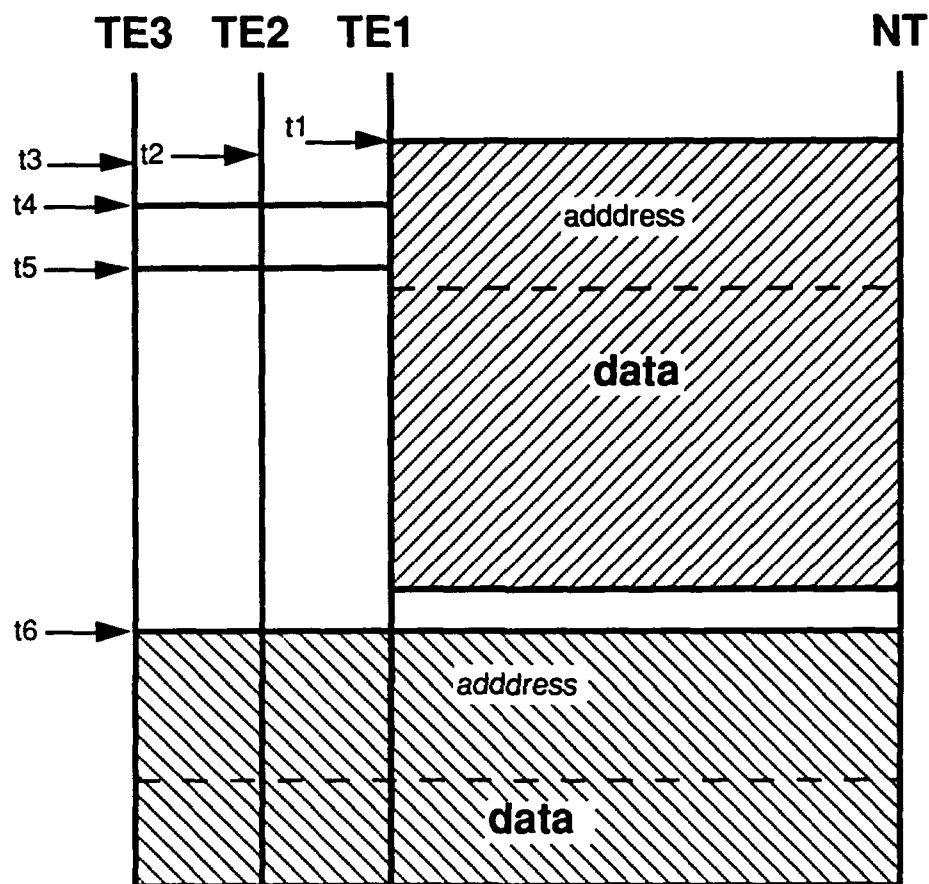
values can be determined without the need to consider the number of active links. The concept used in PRACK and SEPEF can be integrated into a single system such as the basic rate user interface of ISDN.

"With PRACK, substantial portions of channel bandwidth may not be utilized for the user data transmission because of the need to transmit additional S-frames. It is demonstrated that the number of additional S-frame transmissions can be reduced significantly by proper selection of the frame lengths and/or the timing of acknowledgements (deferred acknowledgement). Determining the optimum value of the frame lengths and optimum timing of acknowledgement requires further study.

"It may be not be easy to implement SEPEF on the multiple physical terminal configurations, e.g. basic rate user interface in ISDN, without having extra communication mechanisms among MUXPs at different physical terminals. In the ISDN basic rate user interface, due to the D-echo channel [I.430], a MUXP can receive all the frames transmitted by any local DLP even if the DLP is located in different physical terminal. One possible approach is to make use of the D-echo channel for coordination among the MUXPs at different physical terminals. It is also possible to apply SEPEF in each physical terminal but use PRACK and among the MUXPs in different physical terminals. The solution to this problem is beyond the scope of this study."

Figure 2.2

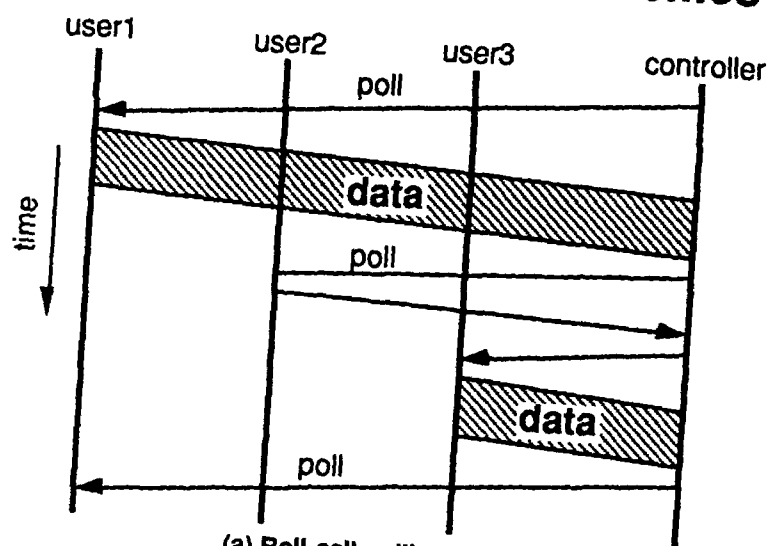
Collision Resolution in D-Channel Access Control Protocol



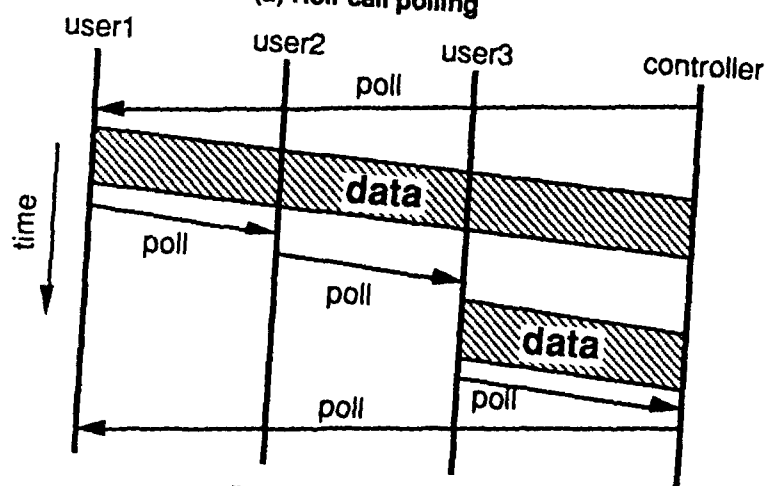
Time	Description
t1, t2, t3	Data generated at TE1, TE2, TE3, respectively
t4	TE2 and TE3 start to transmit
t5	TE2 and TE3 detect collision and stops the transmission
t6	TE3 starts to transmit

Figure 2.3

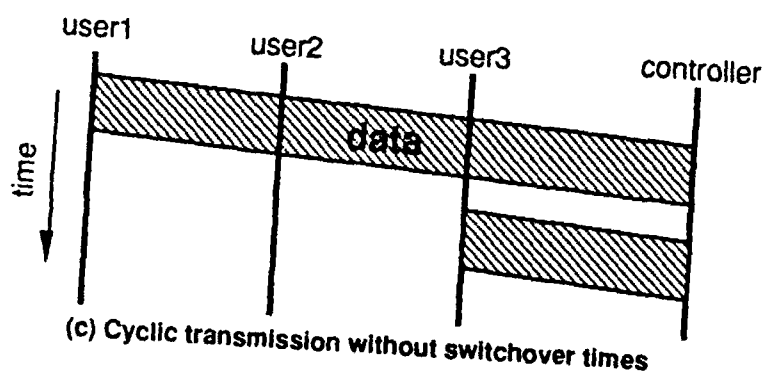
Comparison of Round-Robin Transmission Control Schemes



(a) Roll-call polling



(b) Hub polling



(c) Cyclic transmission without switchover times

**Technical Issues in Evolving to
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Appendix C

ISDN and SS7

ICS 8501 : SPECIAL PROBLEMS

Part 1 : LAPB/LAPD

I- Introduction.

In the packet mode services of ISDN, one could use X25-LAPB or X25-LAPD on the B channel. The choice is not obvious between the former and the latter : some requirements ask for LAPB, others for LAPD. Looking at both the user and the system point of view, what are the points behind using each of them over the B channel ? What are the technical solutions for solving the problem ? What is a new model for ISDN in packet services ?

There is an arising question concerning the protocol architecture to be used when accessing the ISDN packet mode services. It is whether we should use X25-LAPB or X25-LAPD in the place of LAPX in Figure 1, over the line between the user (TA or TE1) and the Local Exchange (LE).

Our goal in this paper is to look closer at the points for each of them and try to constructively criticize the arguments that are discussed in the literature. We will first consider the environment of the problem, and the typical uses that are made of ISDN, and then examine the reasons why LAPD has been recommended.

We will consider the two possible types of terminals that access the network : TE1 is the ISDN terminal, not yet available, that connects directly to the Network Termination point (NT) ; TE2 is the actual X25 terminal, that needs an adaptor to connect to the NT point. These two do use different access techniques : where TE1 uses LAPD, TE2 uses LAPB to the TA, that itself uses LAPD.

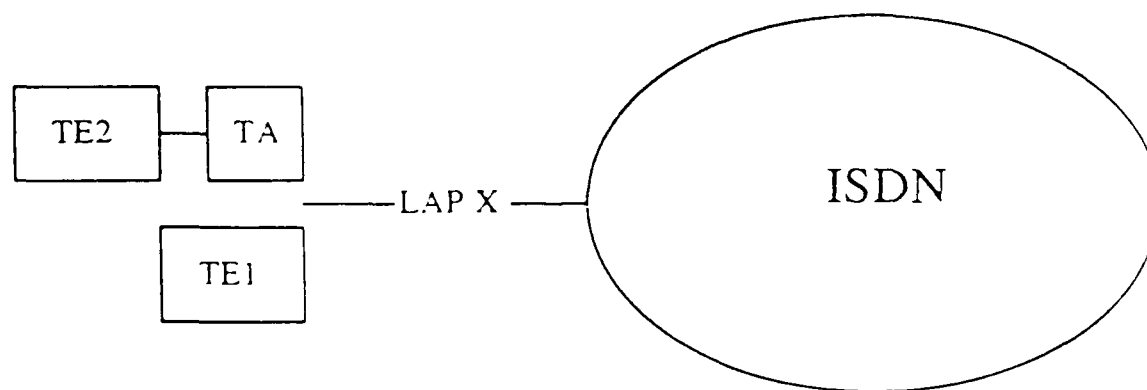


Figure 1 : general ISDN packet mode access

TA=Terminal Adaptor

TE1=Terminal Equipment Type1

TE2=Terminal Equipment Type2

The use of LAPD over the D-channel is of no discussion. It is now established that LAPD is used over the D-channel for uniformly accessing any ISDN service.

The point here is to whether the user should implement LAPB or LAPD over the B-channel when accessing the packet services of ISDN. We assume thus that a connection has been set up between the terminal and the local exchange. The choice will be made under two criteria : the user access has to follow the principles defined under ISDN (access simplicity, uniformity, ...), and the network must the same services with the same quality as those foreseen in the future ISDN.

There are two possible configurations of ISDN-user access to packet services, called the minimum integration and the maximum integration. These two scenarios will actually be consecutively implemented in the network, and correspond to two phases in the development of ISDN.

II- Two Scenarios : Minimum and Maximum Integration.

In the development of ISDN, one generally identifies two phases.

The first one is called the minimum integration scenario, and refers to the case where the user accesses packet services only the B channel. Actually, a pipe is set to a PSPDN node that performs the interworking function with ISDN, and serves the user.

The second is called the maximum integration scenario, and allows the user to access packet services through both D and B channels. The former is used for fast packet switching, and the latter for normal packet switching, with a circuit set up between the terminal and a unit in the network, the packet handler, responsible for servicing the packets.

Before looking at what this means for the access protocols, let us explain what Frame Relaying is, and how it works.

II.1 Frame Relaying : the Backbone of the Reliable Network.[4]

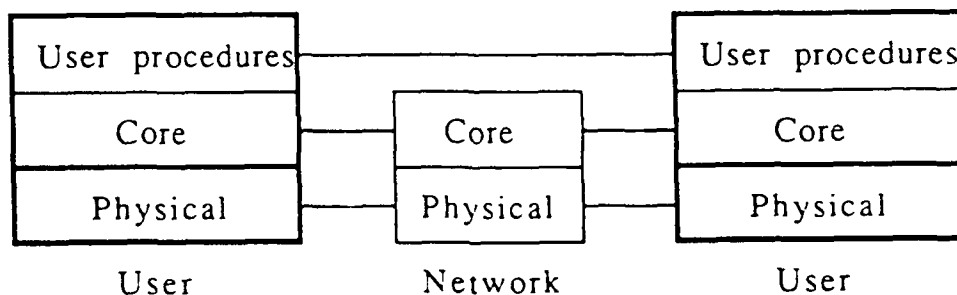
When establishing a virtual circuit between two points, one does not see the extreme overhead implied by the operation of the protocols layer 2 and layer 4 error control and flow control,

In fact, these functions are necessary in a pure sense. They were defined at times where the lines and the equipments were not as reliable as they are nowadays. A lot of error checking had to be

performed, in order to be sure to overcome the possible errors occurring in the equipments.

Now, very low error rates are achieved over physical lines, between equipments that are faster and more reliable. This tendency lead to the definition of a more appropriate mode of transmission : frame relay, to be used in the future ISDN.

Frame Relay is a packet switching technique and is used for packet mode bearer services. It takes the most out of the Data Link layer multiplexing defined in LAPD. In frame relaying, the network functions for data transfer are reduced to a *core*, that allows for minimal network overhead : frame delimiting, alignment, transparency, frame multiplexing, demultiplexing, frame length checking, and detection of transmission errors.



Flow control functions and error control functions are not offered. Errored frames are discarded.

The frame relaying service cannot be offered to non-ISDN terminals, but :

- X31, which defines the access of X25 terminals to ISDN, just encapsulates the X25 services in an ISDN physical layer envelope [4].
- Out-of-band control is a basic characteristic of frame relaying. X25 uses the same virtual circuit for call control and data. They can be separated by providing 2 different DLCIs, and thus LAPB cannot be used.

II.2 The Minimum Integration Scenario.

In this phase, supposedly the first one, ISDN will provide packet services on the B-channel only. The user accesses the D-channel, sets up a 64 kb/s circuit, or pipe, on the B-channel to a Packet Switched Public Data Network (PSPDN) node, responsible for the interworking function between ISDN and the PSPDN it is attached to (see Figure 2). This configuration is interesting for large rates, since we want to

make the best use of the 64 kb/s. However, most of the time, a smaller rate will be used, and the maximum integration phase will provide these smaller rates.

On a protocol point of view, LAPD is used on the D channel and LAPB can be used on the B channel since the minimum integration scenario provides the user with a pipe through ISDN to an interworking node in a PSPDN. This node, even if it may use any of the 33 possible internal protocols in packet networks, would logically require LAPB on the B-channel connection with the user. However, since it is an interworking unit, any protocol could technically be used.

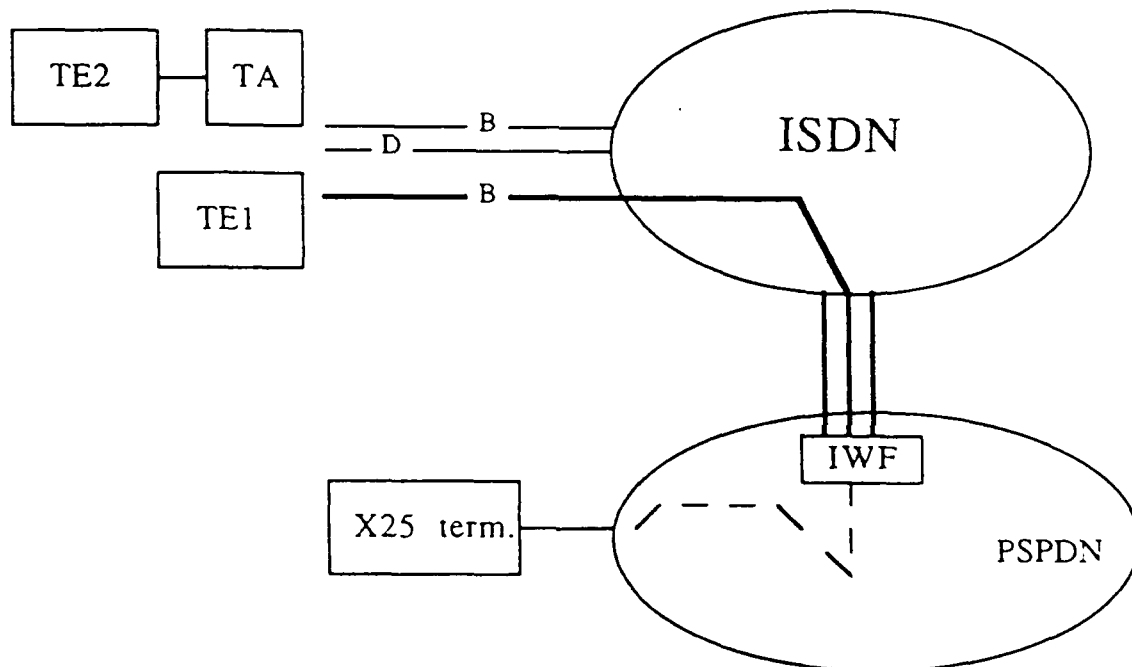


Figure 2 : connection strategy for the minimum integration case

Comparing the use of LAPD or LAPB over the B channel, it seems to us that the following points can be made for each of them :

- Technically, LAPD or LAPB can be used. There is however a conversion required at the TA and IWF functional units if using LAPD on the B channel. There are none for LAPB. LAPB provides for a uniform end to end communication.
- Using LAPD over the B channel would make the user-network interface more uniform, since it already uses LAPD for the D

channel. LAPD provides for a uniform user access to the packet services.

In the minimum scenario, we recommend that the stack used be the one below. Another practical reason for not moving the B channel layer 2 protocol to LAPD is that in the minimum integration configuration, most of the users of packet services are 'old' packet terminals. These terminals use X25 stacks, and replacing all of them would not make sense for the users. The point behind the minimum integration phase is to allow previous configurations to be able to use ISDN services, and users of 'old' packet terminals to move smoothly to ISDN terminals.

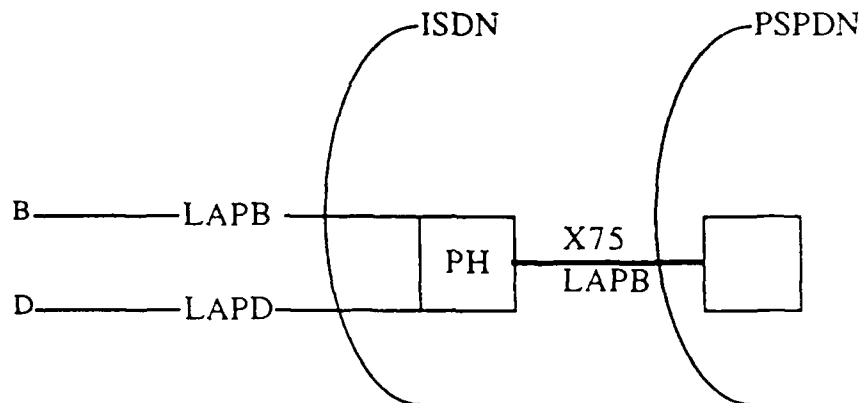
I. 451	D channel	<ul style="list-style-type: none"> - sets up a circuit from user to IWF. - carries control information
I. 441		
I. 430		
X25	B channel	<ul style="list-style-type: none"> - the circuit is used as a PVC. - proprietary user protocol carried transparently.
LAPB		
RS232		

Minimum integration scenario

II.3 The Maximum Integration Scenario.

This scenario is the next stage, after the minimum integration, in the development of ISDN. The basic difference for the user is that he will be able to access packet services on both channel B and channel D. For the B access, the principles are the same : the user sets up a pipe. But this time there is an entity in the network that takes care directly of the packet, instead of routing it to a PSPDN 'server'. This entity is called the Packet Handler (PH). It is not a physical component, like a computer, but rather a function of the network, which can be implemented anywhere : at the local exchange, at the central office, or in any centralized unit. The place where it will be implemented will be function of the level of integration in the network. The ideal, of course, is for it to be as close to the user premises as possible, since a circuit will be established between the PH and the user for packet transmission, as there was a circuit between the user and the IWF in the previous stage.

For the D access, referred to as fast packet switching, the user does not have to set up a circuit. It rather uses the D channel in a datagram manner, sending a packet to the PH, which primary function is to separate control information from user information, the C-plane and U-plane, flowing on the D channel. PH then re-routes the packet to a PSPDN, using the interworking protocol stack X75 or X75'. This interwork protocol uses LAPB in its layer 2.



Maximum integration scenario : packet services access
using the Packet Handler functionality.

The points for both protocols in this configuration are the following :

- using LAPB or LAPD as a matter of uniformity has the same advantages and drawbacks as in the minimum integration scenario.
- There is an additional point for LAPD though, that will be better understood in a later section. LAPD is used in Frame Relay mechanism, instead of LAPB, because it allows for layer 2 multiplexing. As we will see later, this is a fundamental characteristic of Frame Relaying.

Following the previous recommendations, the stack used on the channels should be the one below.

I. 451
I. 441
I. 430

D channel

- sets up a circuit from user to IWF.
- carries control information and fast packets.

I. 451
I. 441
I. 430

B channel

- the circuit is used as a PVC.
- proprietary user protocol carried transparently.

Maximum integration scenario

II.4 Summary.

In using LAPB or LAPD, from the user side, there are equivalent arguments for both of them as a matter of uniformity. LAPB ensures uniformity along the data path to the packet network, and probably to the other end of the communication, since LAPB can be used internally in the PSPDN. LAPD ensures a uniform user access to the network, considering both the B and D accesses.

Depending on the scenario, there is however additional points for each :

- in the minimum case, LAPB is widely used. It is hard to ask the user to change his equipments.
- In the maximum case, if frame relay is used, LAPD is a requirement for a uniform end to end communication.

Actually, these changes are not surprising. The two configurations defined in ISDN correspond to two phases, and two different sets of users. In the minimum case, we are trying to integrate the old users to the network, meaning those who use old terminals with LAPB. In the maximum case, it is assumed that users will have moved to ISDN terminals (the TE1), and thus will have changed most of their equipments.

Discussing the validity of such changes would end up debating on whether the users know where their interests are. LAPD is defined as a 'super LAPB', providing multiplexing and thus allowing for out-of-band control communications. In the few studies that have been published, it was proved that this multiple Service Access Points (SAP) feature, available only in LAPD, introduces a minor

performance impairment [5]. It seems thus that it would be worse than LAPB, on a point-to-point basis.

In the same time, Frame Relay, that uses LAPD, does achieve comparable performances to actual packet networks, if correctly designed. This technique takes the most out of the new equipments that are going to be used in ISDN. It uses simpler mechanisms, and most of all leads to much less network functions.

I do not think that Frame Relay will provide for a 'super network'. However, it is a way of using better quality equipment in a simpler way, and by providing equivalent service characteristics.

III- Comparison of LAPB and LAPD.

The suggestions we made in the previous section are somewhat contradictory. They outline that two different protocols should be used in two different phases. This does not allow for a smooth transition from one to the other.

Rather, we would like to point out the fact that two LAPB and LAPD entities could 'talk' or interoperate, thus simplifying the transition from one scenario to the other. In [2], R.J. Cherukuri proposes to define a LAPD+ that would ensure this transition. Let us first look at the differences and incompatibilities between the protocols.

LAPB was defined much earlier than LAPD, and in fact served as a background for defining the enhanced version to be used in ISDN : LAPD. The biggest difference in the functionalities between the two, and the major improvement on LAPD over LAPB is the multiplexing capability : LAPD can handle as many as 64 layer 3 entities on a single layer 2 connection, whereas LAPB usually handles only one. However this does not enable compatibility between the two protocols, since a LAPB entity communicating with a LAPD entity does not see what is on top of its peer : there could be 1 or 64 entities on top of it, it could still be able to communicate.

III.1 Functional Differences Between LAPD and LAPB.

Let us examine the differences between LAPB and LAPD.

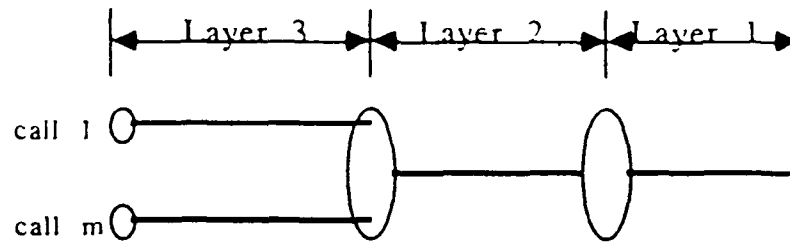
They are both point to point Data Link layer protocols, which means that they essentially perform :

- error control on the frames,
- flow control between the two ends,
- framing.

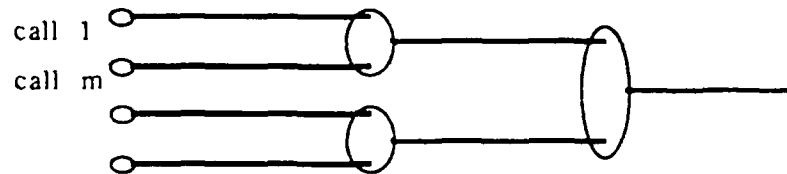
Additionally, LAPD is presented as a 'super LAPB', performing a function that LAPB does not :

- multiplexing of packets over point to point links.

X25 can be implemented on top of both of them, with the same functionalities. One additional possibility, however, is the multiplexing of X25 virtual circuits over LAPD frames, as shown below :



X25-LAPB : no layer 2 multiplexing

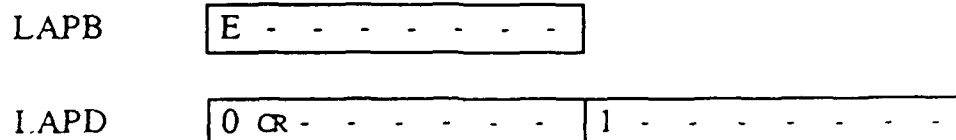


X25-LAPD : layer 2 multiplexing

This functionality is possible thanks to the addressing performed in LAPD, which is based on a Data Link Connection Identifier, that uniquely identifies the Data Link Service Access Point (DLSAP) using the Data Link Layer services. The format of LAPB addresses could allow such a scheme but the operation of the protocol does not. This is one of the reasons why LAPD was recommended as a layer 2 protocol for the protocol stack the future ISDN packet terminals will use. One other is Frame Relaying, that we saw in a previous section.

III.2 Address Field

The basic formats used in both protocols differ in the lengths they use :



They are however compatible in the sense that LAPB's E-bit, used for extendable addresses, is also used in LAPD, and LAPB addresses can be turned to 2 octets addresses.

III.3 Control Field

The control fields are different but LAPB defines an extended version for its control field that matches exactly LAPD's control field :

LAPB										
	0	N(S)		1	P/F	N(R)		I		
	1	0	S	S	1	P/F	N(R)		S	
	1	1	M	M	1	P/F	M	M	M	U

Extended :

0	N(S)							P/F	N(R)	I
1	0	S	S	0	0	0	0	P/F	N(R)	S
1	1	M	M	1	P/F	M	M	M		U

LAPD

0	N(S)							P/F	N(R)	I
1	0	S	S	0	0	0	0	P/F	N(R)	S
1	1	M	M	1	P/F	M	M	M		U

III.4 FCS

Both frames have the same functional field decomposition. However there is a slight difference in one of the field, FCS, or Frame Check Sequence, that allows Layer 2 error control :

Flag	Addr	Con	Info	FCS	Flag
------	------	-----	------	-----	------

LAPB allows for a 32 bits FCS, whereas LAPD allows for a 16 bits FCS field only. This improvement is due to the improvement in reliability of ISDNs over PSPDNs, and particularly to the technology and links quality. This difference proves to be a problem since each entity

using a different size for this field might mix Info bits with FCS bits and vice versa.

We did not find any recommendation in the standard or any implementation in the literature that allows for a reduced FCS field in LAPB.

III.5 Operation.

LAPD and LAPB define two main operation modes : acknowledged or unacknowledged, and do coincide on this point.

LAPD makes a difference in the two ends of a point to point communication, and differentiates the network side from the user side. This difference appears in the use of the C/R bit in the operation of the protocol :

LAPD

Function	Direction	C/R
Command	net -> user	1
	user -> net	0
Response	net -> user	0
	user -> net	1

LAPB does not make any difference between the user or the network side : commands have C/R=0, and responses have C/R=1.

This is a big difference between the two protocols and the only way to have a LAPD and a LAPB entities interoperate is to change one of the protocols, or use a bridge that terminates the two protocols on each side.

There is another big difference : I-frames are commands only in LAPD, whereas they can be commands or responses in LAPB. This would result in a LAPD entity resetting the line if it received an I-frame from a LAPB entity, intended as a piggybacked acknowledgement, but taken as an error condition by the LAPD entity. All other frames have the same Command/Response meaning in the two sets.

However, LAPB here defines much more frames than LAPD does. In fact it contains several additional frames, most of them due to the initialization capability offered at this layer by LAPE. These are :

- SIM frame and its responses DM (Disconnect Mode), RD (Request Disconnect), and RIM (Request Initialization Mode).
- TEST frame.
- SREJ frame for the selective frame reject.
- UP and RSET frames.

This does not prove to be a big problem between the two protocols since we can still enable the use of the frames that are not understood.

Also, the FRMR frame, used in the frame rejection mechanism, is never sent by a LAPD entity, although understood and proceeded if received, and a SABME is rather used in these conditions. This is not an incompatibility between the protocols.

The last frame that causes problems is the XID frame used by an entity to request identification of, and some information about its peer entity.

In the operation of the protocols, there is a major point that would not allow interoperation : LAPD allows an I-frame to be retransmitted on timeout conditions (meaning on an acknowledgement timeout), LAPB does not. This situation could cause a LAPB entity to receive a duplicate frame from its peer entity. As a consequence, LAPB resets the line.

Also, in LAPD, the Poll/Final bit is set to 1 only in timer recovery procedures like acknowledgement timeouts ; in LAPB P can be set to 1 anytime.

III.6 Internal Structure.

Concerning the internal structures, the differences are minor, and do not affect the interoperability. Can be outlined :

- Timers are not the same.
- The number of states defined for the operation of the two protocols are different.
- LAPD uses dynamic windowing for flow control, LAPB uses sliding fixed-size windowing.
- Delays are slightly different due to I-frames being commands only in one case, and commands/responses in the other (allows piggybacked). However, some studies showed that the

difference is not important, and using mechanism as multirejects can significantly improve the performances [1].

III.7 Some Interoperating Scenarios and a Suggestion.

In order to have LAPB and LAPD overcome their difference, there are 3 scenarios :

[a] modify LAPB so that it operates with LAPD.

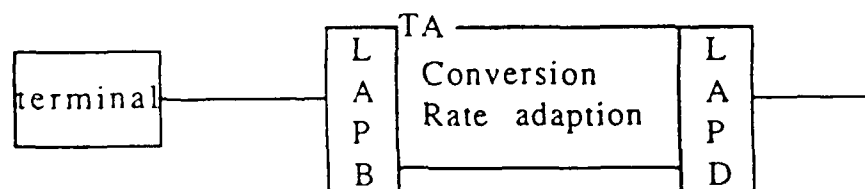
[b] modify LAPD so that it operates with LAPB.

[c] define a LAPD+ that makes the link between the two.

Scenario [c] is described in [2] and is useful in a LAN-ISDN interconnection environment. Our purpose is to study the impact on X25 terminals access to ISDN of a change in the protocols.

As defined in [3], two possible means to provide packet services : over B or D channel, and two phases in integration. In the first phase, access is only over B-channel, with an ISDN circuit going from the user to a PSPDN access node. In the second phase, ISDN has some packet handling facilities, and takes care of the packets itself, with a circuit going only from the user to the ISDN packet handler.

The problem is that when accessing the packet services, the user either uses the D-channel as a packet-channel, or establishes a connection between the user and an eventual packet handler. This aspect cannot be changed, but by modifying the protocols, we can allow X25 terminals to use their own protocol to set up a circuit in ISDN :



By matching LAPB/D, the TA functions become simpler. Setting up a circuit over the D-channel can be made by using X25-LAPB of the terminal. However one still cannot use X25 directly over the B-channel without having it set up using the I.451 procedures.

Now the choice between [a] or [b] would consider the following factors :

- X25 is a widely used protocol, meaning that a lot of terminals and applications use this stack for their communication. Modifying LAPB is equivalent to modify X25.

- LAPD is not as widely implemented and used.
- Considering the few modifications, concerning C/R bit use, I-frames allowed as responses or not, retransmission of I-frames, modifying LAPD seems technically simpler.

We suggest thus that LAPD be modified in order to :

- provide symmetrical use of the C/R bit. This drives to no more distinguishing the user side from the network side.
- Not allow I-frames to be retransmitted on timeouts.
- Allow for piggybacked acknowledgements.

These few changes allow for interoperation, and use of LAPB in call control over the D-channel, uniformizing the use of packet services in ISDN.

IV- Summary of the Arguments.

In the previous paragraphs, we stated the following :

- On a functional basis, LAPB and LAPD are different in that LAPD provides multiplexing of data link connections on one media.
- On a protocol basis, few differences appear, and the two protocols can even interoperate if a few changes are made.
- On whether to use LAPB or LAPD over the B channel for packet access, the uniformity arguments were raised for each of them : LAPB makes the end to end connection more uniform, whereas LAPD makes the user's access more uniform by using only one data link layer entity on the user's side.
- An additional point was made for LAPD when the use of frame relay technology is foreseen in the network. Frame relay uses LAPD as an edge terminating protocol.

In the coming discussion, we would like to look closer at the validity of these arguments :

- the implementability of a common data link layer on the user's equipment for both D and B accesses has to be examined closely.
- Frame relay, its concepts, assumptions and mechanisms will be criticized in order to contribute to the raising question of

whether or not implementing it is worth it. More particularly, we would like to look closer at congestion control and flow control, which are big issues in frame relay networks.

V- The Common Data Link Layer.

V.1 Input/Output : the USART.

At the physical level of any communication, one finds a port and its controller for the transmission (see Fig. 1). The current name for the unit is Universal Asynchronous Receiver/Transmitter (UART) or Universal Synchronous/Asynchronous Receiver/Transmitter (USART).

A port is generally a microprocessor, with its own clock, its memory and registers, and a processing unit. The intelligence of a port is highly variable, and can include very few to a lot of functionalities. Currently, it includes up to layer 2, or part of layer 2, functionality. Concerning ISDN, the interface is built onto a card that plugs into a computer. LAPD is implemented in the hardware, since simulations proved that a software implementation is much too slow for a real application purpose. Our purpose is to study whether or not a common utilization of the LAPD unit by the network layer softwares of both D and B channels is possible.

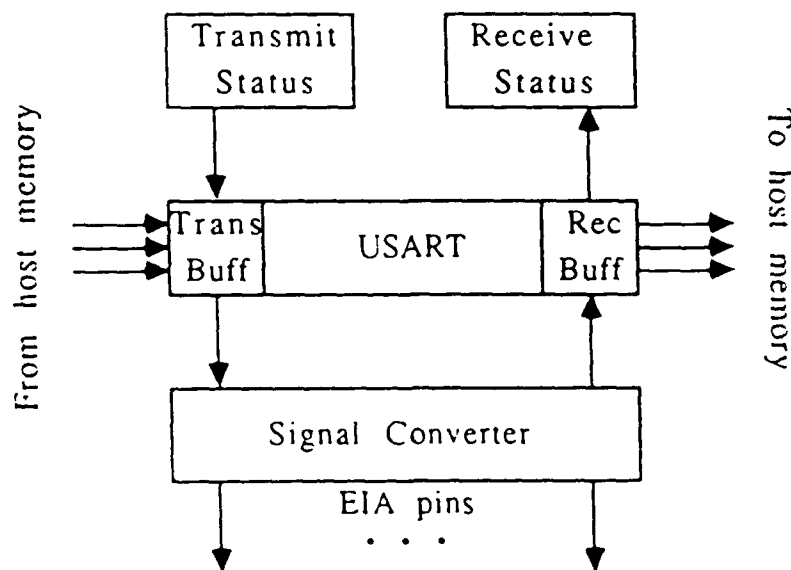
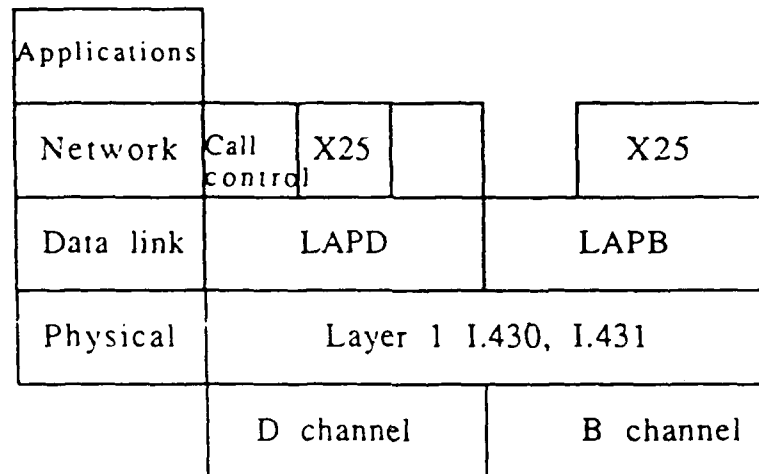


Figure 1 : USART from [7].

V.2 General ISDN Interface.

The structure of the ISDN interface on the user's side is described in [6] :

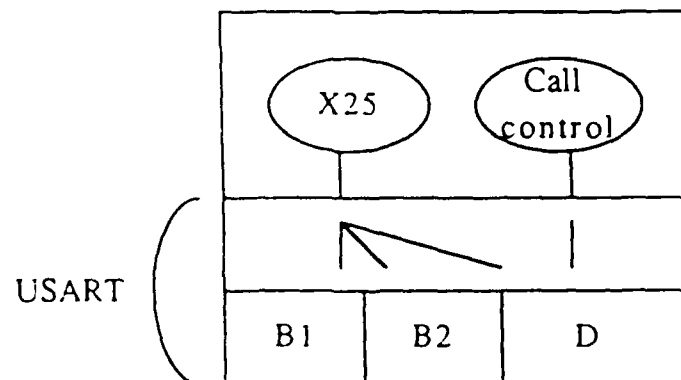


The actual physical layer is I.430, I.431. The data link layer is LAPB or LAPD, and the layer 3 is I.451, X25,

If LAPD was to be used only, it would replace LAPB on the B channel. The new architecture is detailed in the next section.

V.3 Interface Architecture.

The ISDN interface for packet services will follow the structure above, and implement the required stack of protocols on a card that would have the following architecture :



The USART will implement up to layer 2 and embed the LAPD entity. At the layer 3 we will be using X25 on the B channel in the circuit mode (or minimum integration scenario), and also on the D channel in the packet mode (or maximum integration scenario), and the call control entity.

Let us suppose now that there is a single layer 2 module that serves both layer 3 modules X25 and I.451.

From the LAPD definition, we know that the protocol distinguishes between the layer 3 entities it serves by looking at the Service Access Point Identifier, or SAPI. Depending on the values of this number, different types of connections are made up :

SAPI=0 is for Signaling Information or Call Control procedures.

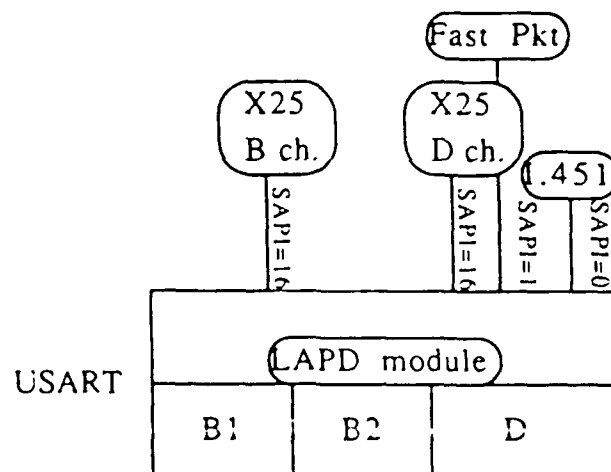
SAPI=1 relates to packet mode connections over the D channel with I.451. This service is referred to as Fast Packet Switching.

SAPI=16 designates X25 level 3 communications or packet accesses on the B channel.

SAPI=63 is reserved for management communication.

From these values, it turns out that a single LAPD module cannot serve layer 3 entities for accesses on both B and D channel. A typical malfunction would occur like in the case below :

The D channel can carry control information, that is directed to the I.451 layer 3 entity with SAPI=0. It also sends or receives packeted information through SAPI 1 and 16. If the same LAPD module takes care of both B and D channel types, it will not be able to differentiate the packets that are directed to B channel layer 3 packet handling entities from the ones that are directed to D channel layer 3 packet handling entities.



As shown in the picture, the same SAPI is carried over two different types of communication. It is thus impossible for a single LAPD entity to service an X25 D channel module and an X25 B channel module.

Such a differentiation would be possible by renumbering the entities and assign different numbers to entities that refer to B channel communications or to the D channel communications. For example, SAPI=16 could be X25 D channel layer 3 entity, whereas SAPI=17 would represent an X25 B channel entity. This has not been done by the standards committees ; I suppose it is because LAPD is designed to be the data link layer of the D channel.

V.4 Implications.

In the previous paragraphs, we identified a uniform user access as being an advantage for LAPD over LAPB. It appears that a single entity cannot be used for performing the data link layer functionality commonly to D and B channels.

This is due to the early definition of LAPD as being the data link layer of the D channel, and probably to the fact that the control software for D channel communications interfaces with the D channel at the data link layer, whereas the control software for B channel communications interfaces with the B channel at the physical layer.

In discussing this possibility, another point arose against the use of a LAPD entity as data link layer of an X25 module on the B channel :

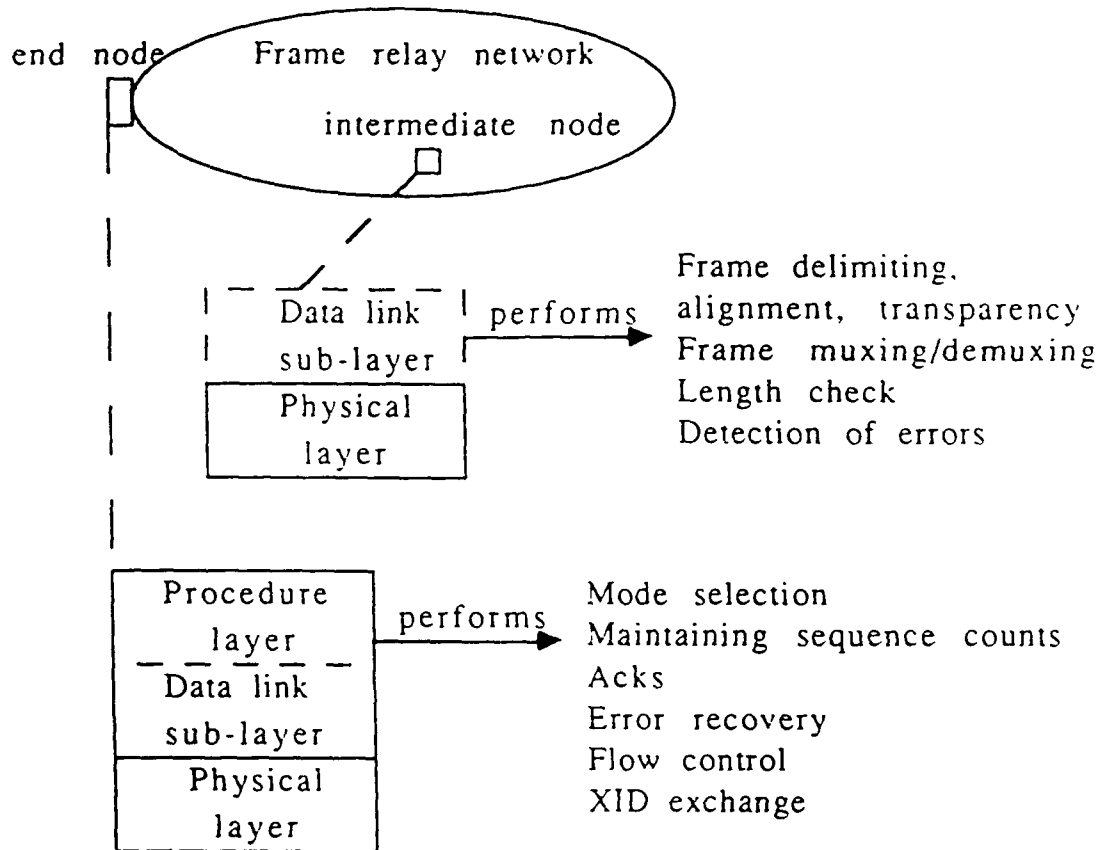
- multiplexing will not be used as it is defined in LAPD, since the data link will only carry user information from a single layer 3 entity that already performs logical channel multiplexing.
- Using a LAPD entity is finally equivalent to use only the SAPI=16 data link connection, since on the B channel there will not be any entity with SAPI=0 (signaling), SAPI=1 (fast packet) or SAPI=63 (management).

VI- Frame Relay.

VI.1 Principles.

The idea behind frame relay is to reduce the amount of processing performed in the network's nodes on the user's data. This is achieved

by using only a subset of the data link layer's functions in the intermediate nodes, and terminating the data link connection on an end-to-end basis, instead of a point-to-point basis (see Fig. from [8]).



We talked about frame relay in an earlier paragraph, but some points were not addressed in our discussion : congestion and flow control, particularly.

This problem is raised in many papers in the literature, and it seems that a lot of people try to address what is probably the biggest concern in dealing with frame relay networks. The next table establishes a comparative study of the congestion control mechanisms found in X25 and frame relay networks.

	X25	Frame relay
Link by link	RR frame of LAPB (choke)	<ul style="list-style-type: none"> - priority classes and separate queues at DL sublayer. - stop message, drop frames.

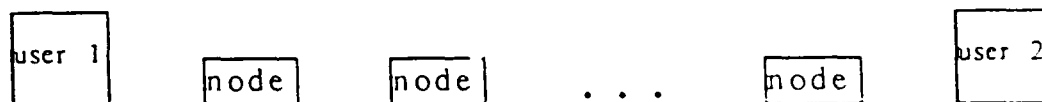
End to end	- choke packet - transport credits	- RR frame of LAPD - adaptive window
Entry to exit	- entry tickets	same as link by link

As a summary on congestion control and a concluding statement on it, we would like to point out the general attitude about congestion and flow control in frame relay networks :

- it is a much more complex to solve in frame relay networks than in regular packet networks, because FR nets are much more sensitive to flow control problems. Congestion is solved by dropping frames, whereas X25 uses its data link layer flow control to handle the problem in the network.
- Every solution reports the flow control load on the user, because the network does not handle anymore the extra overload, and does not perform any other flow control function than throwing overflow frames away.

Error control is also an aspect that is really different from classical networks to frame relay. The main difference occurs on a point to point error control that frame relay does not perform anymore. Frame relay just discards those frames that the sub layer detects as being in error, letting the end user time out on the loss, whereas in an X25 network, the receiving node would ask the previous node to repeat its transmission. In all cases frame relay networks time out on the transmitter's side, whereas in X25 networks, nodes send negative acks to each other along the path, thus not timing out any time a loss or an error occur. The loss is considerable when errors occur in FR nets :

if we assume a 10 hops path between two users,



$$\text{X25 timer} = \text{point to point delay} + \epsilon$$

$$\text{FR timer} = 10 \text{ point to point delay} + 10 \times \epsilon$$

On a per packet point of view, the time before recovery might be 10 times larger in the case of a FR network. In most of the cases, it is

even more because the next node in the network will ask for a retransmission, that will occur at once.

However, the overhead of X25 processing is sometimes estimated to 10 times longer than the regular FR processing [9].

Another point for X25 is that the window will probably be larger in FR than in X25, because silences have to be as short as possible before receiving acks. A loss would thus cause more backup, and more frames to be retransmitted.

A point for FR is however that routing will be much faster, because performed earlier in the processing (one layer below), and so is multiplexing.

As a summary, FR nets are much more sensitive to environment with errors, but a basic assumption to their implementation is that equipment used make less errors.

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ICS 8501 : SPECIAL PROBLEMS

Part 2 : Signaling System 7

I- Introduction.

Signaling System n.7 (SS7) is the protocol used in the Common Channel Signaling Network (CCSN) that implements the signaling function in ISDN. This protocol allows for transmitting signaling messages between Signaling Points (SP) and Signaling Transfer Points (STP). It is an internal protocol to the network. In this part, we will look at the user involvement in signaling, and at the impact on the user and the network of 'delivering' SS7 directly to the user.

In a first part, a description of SS7 and CCSN is provided, and the interaction with the actual user is also provided.

In a second part, we come up with a description of what would a full access by the user to SS7 look like : benefits, requirements, constraints and new architecture. After deriving the side 'effects', a new proposition is made that leads to defining new services for the user.

II- Signaling System 7 : an overview.

II.1 Basic concepts of a Common Channel Signaling Approach.

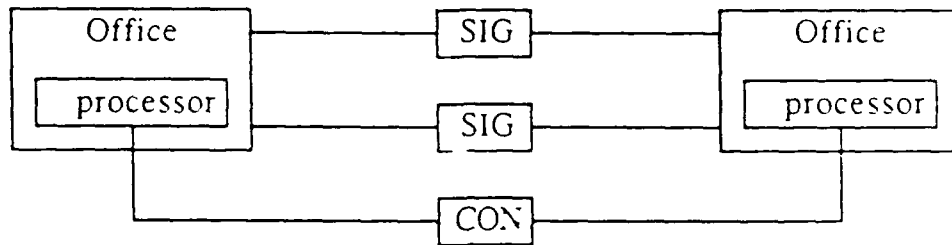
Back in the telephone golden ages, the entire public network was dedicated to telephony, and remained so until the computer brought this need for exchanging data between subscribers, and most of all the digital concept that would change the technology forever.

In every communication, there is a need for control signal. In fact, no communication can ever take place without control : information has to be coded in a way that both communicating entities understand, and there has to be some signals between them saying that they are addressing each other, talking to each other, and ending a communication.

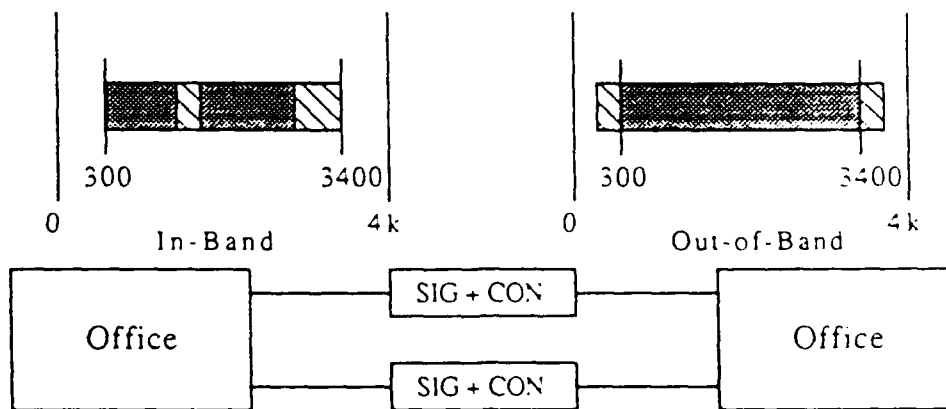
In the telephone world these signals are : dialing, dial processing, ringing, busy, answering, ... signals. In the early ages, these signals were exchanged within the bandwidth of the transmitted signal (the human voice). This technique is called In-Band signaling, and represented in Figure 1. Another technique for signaling is called Out-of-Band, and signifies that the signals are not carried at the same frequencies than the voice signal, as shown in Figure 1. These two modes refer to an InChannel signaling, meaning that the same trunk is used for signals and signaling. This presents the following drawbacks :

- The information rate is limited, due to the two overhead of control on the information channel.
- The delays in establishing a connection are large, and need to be reduced.

These problems can be addressed using common channel signaling, as illustrated in Figure 1. Here offices exchange digital control signals over dedicated channels. This gives a more powerful signaling possibility, optimizes the service delays, the bandwidth utilization, and improves considerably the network management applications, as we shall see later.



Common channel signaling technique



In-channel signaling technique

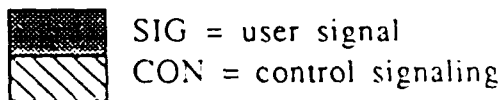


Figure 1 : signaling techniques

Common Channel Signaling (CCS) allows us to separate information and control, thus having transparent digital information communication over the trunks.

II.2 Protocol Architecture.

The architecture of SS7 is shown in Figure 2 and is composed of :

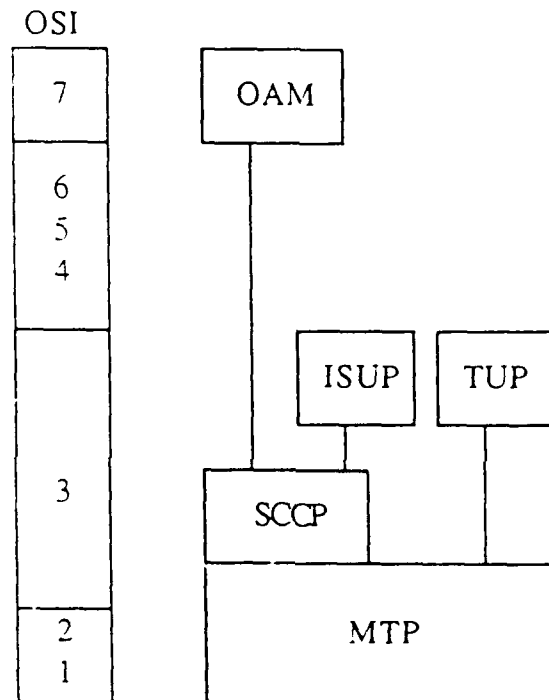


Figure 2 : SS7 architecture [1]

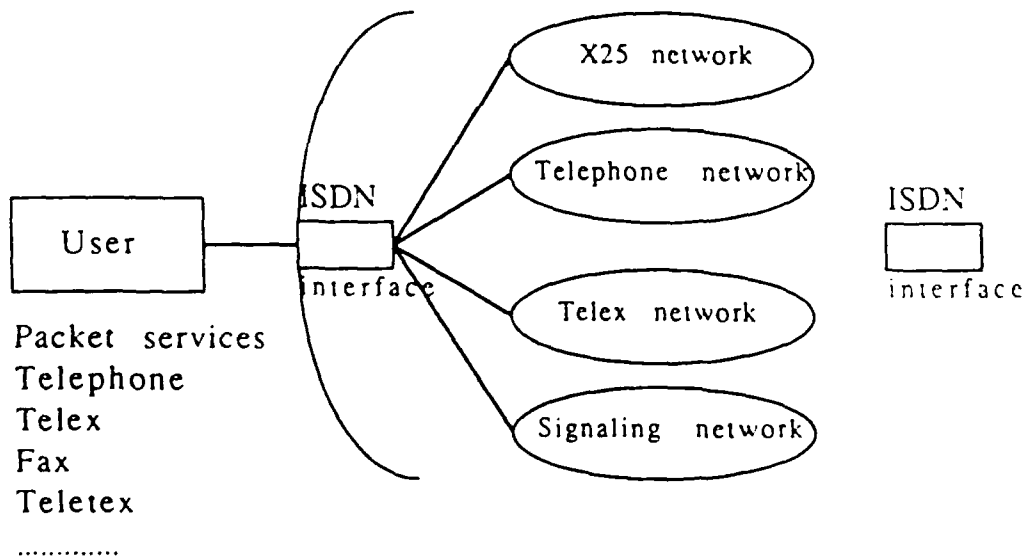
- Message Transfer Part, or MTP : in charge to provide with a connection less transmission of control signals. It provides a datagram service for the exchange over the signaling links.
- Signaling Connection Control Part, or SCCP : SS7 will have to provide with connection-oriented communications, this one of the roles of this part. It also provides with a full global addressing that complements MTP addressing (in fact MTP allows only to address the STPs or SPs on a 14 to 24 bit addresses base, which is not enough for process and user addressing).

- ISDN User Part, or ISUP, provides call-related services for ISDN.
- Telephone User Part, or TUP, provides circuit-related services for telephone call control.
- Operations, Administration, and Maintenance, or OAM, covers the network management functions.

II.3 Function in the Network.

SS7 is used for interoffice signaling. This means that it is an internal protocol to ISDN, and is used for transmitting control signals between two ISDN-network nodes.

The CCSN is one of the logical networks involved in ISDN. The principle behind ISDN is to offer a general interface for all services, but the network is not designed to implement actually all these services. This is not realizable, because there are too many services that require too many different performances. Rather, ISDN will implement the general architecture below.



The CCSN, or signaling network, can itself rely on another physical network, and just add its protocol architecture and functionalities. The figure could actually be misunderstood in the sense that the user does not directly issue signals that travel through the signaling network. Whatever he issues is considered as being information by the interface. Even user-to-user control signaling travels through the data networks, and not the control network.

What is the user involvement in the use of SS7 ? We would be tempted to say none. The only control interface between the user and the network is the User-Network Interface, defined in the I.4 series as I.430, I.44x and I.45x of the CCITT. There is an interaction between control signals that the user accesses through these protocols and some parts of SS7, the ISUP. Actually, ISUP is no more than I. 451 with additional functions and features, and there is a direct mapping between them.

However, there are more and more applications that require a bigger involvement of the user in the public network resources control. Among these, a LAN to LAN connection through ISDN, using its flexibility and power. Such users want also some management services. We will take a look at these applications in the next part.

III- Delivering SS7 to the User.

III.1 Uses of SS7.

Clearly, there are a lot of new services that are proposed to the user through ISDN. It first integrates all the different accesses to different networks in a single interface.

SS7 is the way of controlling the public network. Giving it to the user will have to take this parameter into account : if all users have control over a pool of resources and this control is not organized or regulated, the efficiency of the network resources, and eventually the service offered to the user, are going to drown drastically. It is well known that centralized controls generally ensure a strict use of the resources, however it is not fault tolerant, and flexible. Distributed control is preferable, and our goal will be to obtain some sort of distributed control of the resources of the public network, by designing a user control policy.

It seems that the user applications that require a real control of the public network are rather 'big', and include some data communications applications.

A good example of this are the Virtual Private Networks, in which a user has access to resources of the public network, and uses them as if they were part of a private network he would possess. This kind of application is generally software defined, and the user needs some way of managing data bases for configuration, accounting,

A second example is more oriented towards telephony, and is referred to as Feature Networking in [2]. The user here is generally a corporation that has a set of agencies throughout the country. It

wants to be able to interconnect, for telephone as well as for data communications, its agencies and their workers using an internal, simplified addressing scheme. The result is that several locations appear as one for communications, and they are transparent across geographic locations. Such services include location code dialing plans, centralized numbering plans, ...

A set of general requirements from the users, independent of the applications has been identified in [2], as :

- interactive bandwidth capacity modification.
- creation, modification and storage of different network configurations to be implemented at different times.
- creation of a schedule that go with.
- network monitoring in real time.
- accounting for each user individually.

Finally, we can note that the general idea of user control over the network is a full ability to manage their resources, including Fault, Configuration, Accounting, Performance and Security, the five functions defined in OSI management. We will aim at providing a distributed management scheme that will include delivering SS7 to the user, and providing a control scheme that still allows for an efficient share by the users of the pool of public resources.

III.2 A Virtual Public Network.

In today's ISDN, the user has access to control functions through I.451, or the D-channel protocol for signaling, as shown in Figure 3. It is called the network interface and is basically a subset of ISUP, the ISDN User Part we already saw.

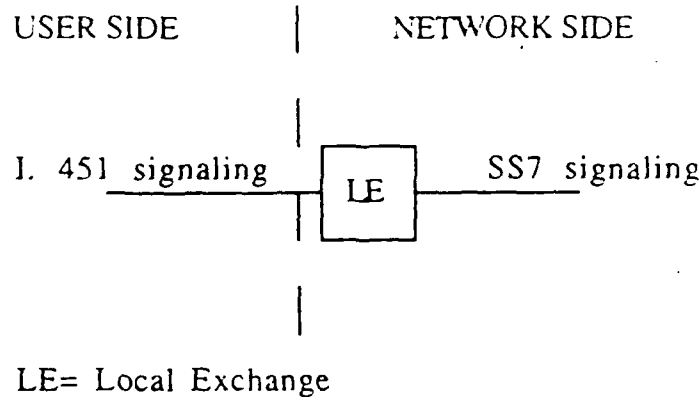


Figure 3 : correspondence between I.451 and SS7

The new approach that can be envisaged is based on the delivery to the user of SS7 as a whole, as shown in Figure 4. It provides him with the same control signals as before, plus some capability for managing the public resources. In order to still have an efficient use of the network, the new services are provided as requests, instead of commands. Basically, SS7 is now divided in two parts : the first one concerned with call control (or all parts up to level 3 in Figure 2) procedures is provided as commands, as it was previously. A telephone user will issue a call in the exact same way.

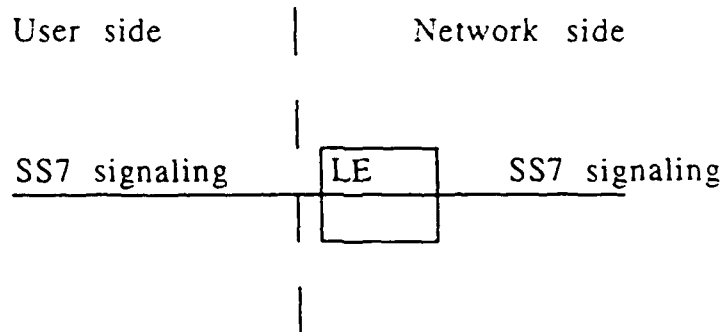


Figure 4 : a new approach.

The new potential is now for users with more developed applications, using PBXs, MUXs, ..., who will be able to monitor the public part of their network, as if it effectively belonged to them. Figure 5 shows some of these possible customers.

They can dispose of the whole SS7 parts, and thus send commands for reconfigure their public lines, modify their associated bandwidth, ask for a momentarily new service. This improves the service

flexibility, and eases the user's network evolution. It will simplify the access to the control procedures on the user's side and simplify the functionalities previously needed in the user's interface to map the user's and the network's protocols. It modifies also considerably the management architecture, as we shall see in the next paragraph. However this raises a big problem of security for the network provider : if it allows all users to command the network components, it needs an authority for solving the possible conflicts, and controlling that the modification asked for by the user will not drown the network service.

This problem is solved by adding a network controller. This entity is represented on Figure 5, and seems to be a central point of the network. However, since the control is to be distributed among the users in customer control entities, we recommend a geographically or functionally distributed network controller. The architecture to be adopted depends on the architecture of the network. For example, in the North American telephone network, a good architecture would consist of having a network controller responsible for allocating the resources to users on a per-area-code basis. This means that a user submits a request for, say, reconfiguring half of its links. This request goes to the local network controller, that allows this manipulation by sending the appropriate command to the appropriate switches, or disables it.

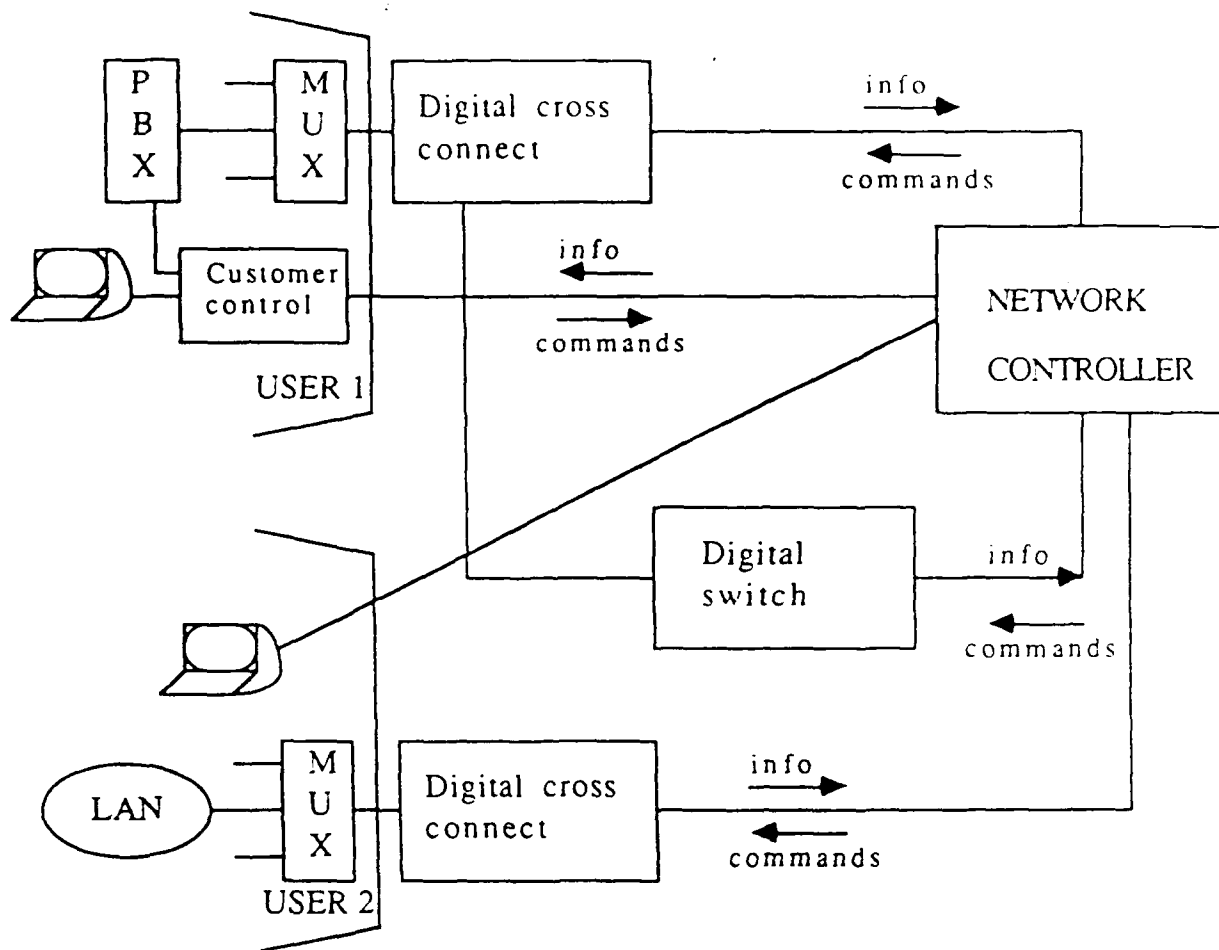


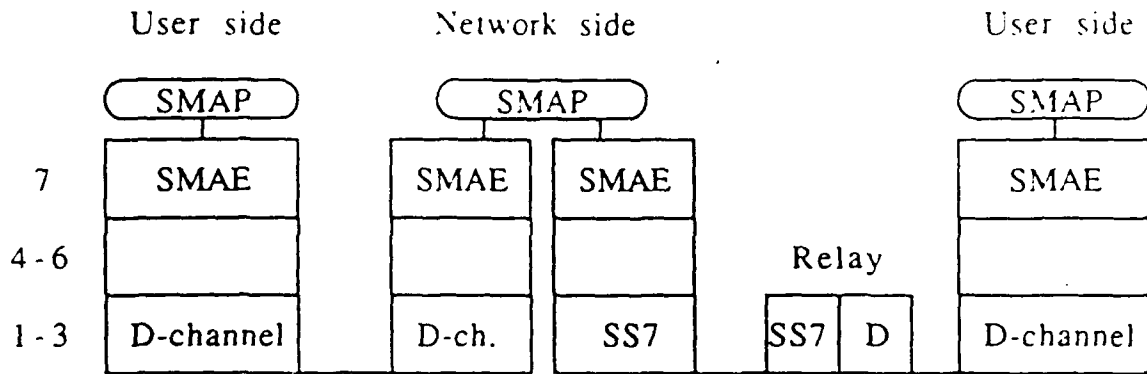
Figure 5 : an example of use of SS7. [3]

As one can see on the picture, each user has a controller, that sends commands to the network controller, but only the network controller sends commands to the network resources. This allows him to check for the user's requests.

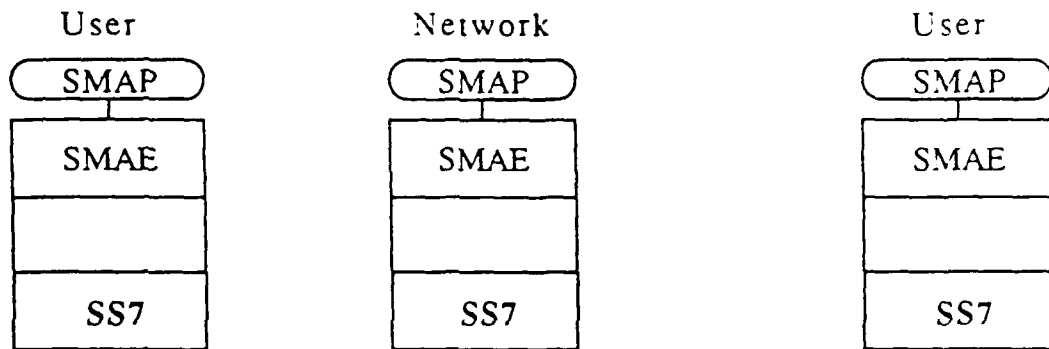
III.3 Implications.

The first implication is on SS7. It has to be slightly modified as to allow for a command-response operation mode.

The second and more important one is on the network management point of view. Figure 6 shows the architectural difference in providing the user with SS7.



User access and management before



User access and management with SS7

Figure 6 : difference in network management view

With SS7, the control becomes shared, and the user has practically the same role as any other administrative entity in the network, see Figure 7.

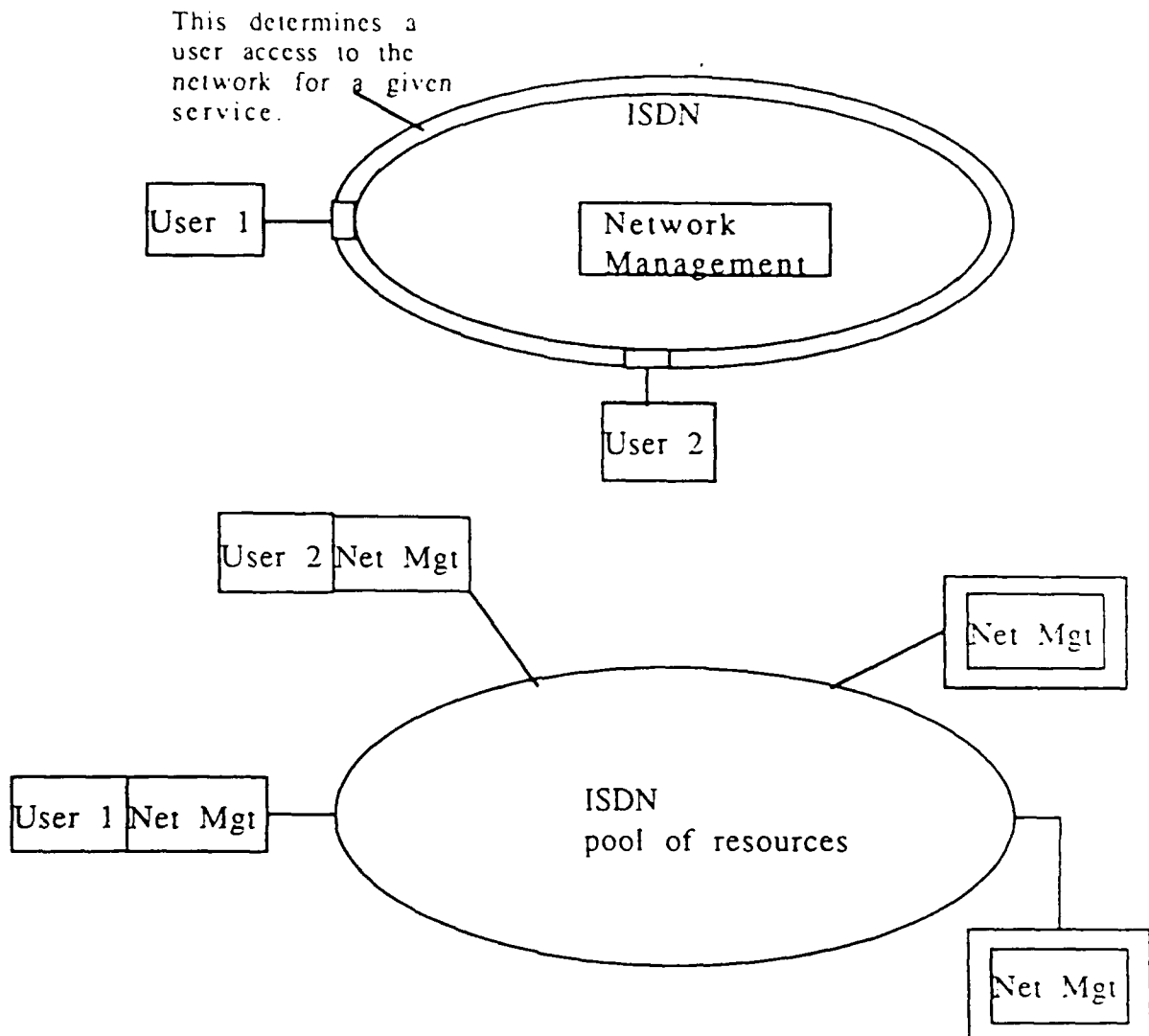


Figure 7 : difference in network management

This has to be done under the following constraints :

- There has to be a control entity in the network so that the users do not overuse the resources in a sense that would cause performances, and other users services, to decrease.
- The FCAPS defined in network management become integrated, the service has also to be evaluated on a per-change basis, per-use basis.
- There has to be some bounds to the possibilities offered to the users to manage the public network. These can be

determined by contract, and used during negotiation between the user's control entity and the network controller.

- Priority has to be given to the network controller messages in order to be able to monitor the network in all cases.
- Priority has also to be given for normal control messages, related to call control, over those new messages.

IV. Another Strategy.

IV.1 Critique of the Previous Approach.

The virtual public network approach sounds ideal to users, but it will probably produce a conflictual situation when applied to such a general network as ISDN, which supposedly offers all services. For example, telephone users should not be given the opportunity to control the network, whereas ISDN interconnection of LANs should.

All the users transmit requests to a network controller, in charge with controlling the validity of the requests, and their applicability to the actual resources. The conflict arises from the situation where two requests arrive and are incompatible : for example, two users could ask for the allocation of the same equipment.

A practical solution is very difficult to find in these conditions, and in fact the decision the network controller would have to do would be unfair, or undeterministic.

Furthermore, there are quite a set of drawbacks in providing all users with the possibility to control the network :

- The network becomes very complicated, because the control comes from all the users.
- Congestion problems may arise that are not expected, and tear down the network performances, or even prevent a normal operation.
- Delay and availability become critical on the Common Channel Signaling Network, where the users' requests are carried out.
- Users with simple equipments, not requiring elaborate management functions like telephones, fax machines, videotex terminals, ..., do not need these elaborate functions from ISUP, SCCP,
- The burden of buying a full stack for managing the public equipments would not be negligible, both in cost and time.

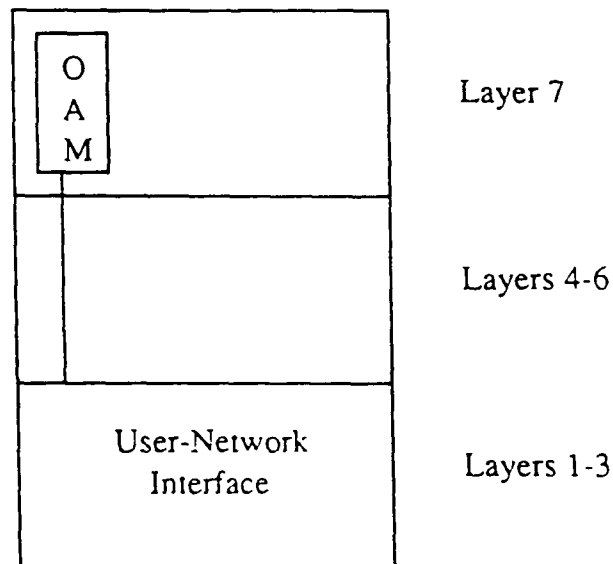
IV.2 Management is the Main Thing.

We identified the management goals as being the only functions the users are interested in in controlling the network. Taking the critique into account, a more implementable solution is possible.

It is based on reducing the number of users that access the public network control services. The one that will be offered these services will pay an extra amount, and this should make them affordable for only LAN to LAN applications. Those who have LANs, or large equipments like PBXs, interconnected through ISDN will be able to control the public part of their network.

The new approach consists of only providing the user with the management functionality of SS7, equivalent to the OA&M component, an application layer functionality. Providing the user with only one part of SS7 reduces the additional time and money cost of adding parts to the user interface.

This module has to communicate with the public network management entities. This can be achieved through the existing User-Network Interface :

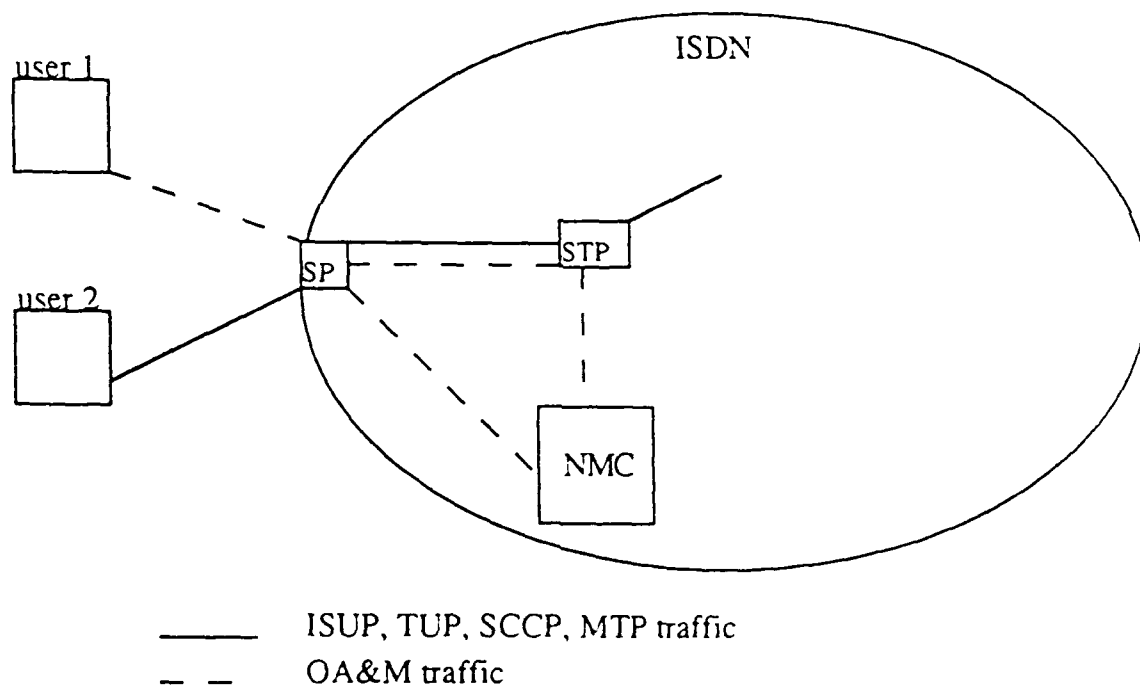


In any network, there is an entity that controls the equipments, either central or distributed. We will refer later to this entity as the Network Management Center (NMC). The user will communicate with it for all his management problems concerning the public resources, sending requests and receiving responses. The NMC allows, just like the Network Controller of the previous approach, some control over users' commands to the network's equipments.

This is a less complicated structure than the first solution, and more flexible in terms of who will be offered management services.

A problem still remains to be solved. Let us imagine we have an OA&M module, that allows us to control a digital cross connect for example. We do not want to know what the local NMC's address is for sending a command. What we want is to be able to use the OA&M format over the D channel, and that the commands go by themselves to the NMC responsible for our requests. On the other hand, a carrier does not want to provide the user with physical addresses in the network, for example the local NMC, for obvious security and traffic control reasons.

To our mind, the solution is to define a special DLCI for the OA&M communication exclusively. Any active OA&M would send any request on the D channel with a predefined Data Link Connection Identifier (For the moment 0, 16 and 63 are defined and used). The communication on the D channel would follow the path below :



NMC is defined as being an SP, or Signaling Point, generating signaling traffic, whereas the Signaling Transfer Point STP just routes the signaling traffic.

The routing at the initiating SP is made on the DLCI number. User's requests end at the NMC, that answers to the users, communicate information and initiate commands to the equipments according to the requests.

IV.3 Security Issues.

The main problem behind providing the user with a way to control the network is security. Public networks are stable and robust in the sense that they can handle any normal user load with the same performances, and extra load with a small degradation. They do not fail in normal conditions. The main interest in providing the new services is to guarantee no robustness alteration. The user must not be able to create failure conditions, by monopolizing all equipments in a zone for example, and the commands issued have to keep the network secure.

In order to ensure this, the following steps should first be followed :

- Services should be categorized, and contracted by categories. A contract number will be exchanged at the first access between the user of the management services and the NMC, along with any pertinent user information, in order to ensure access control.

The communication with the NMC in a Request/Command order should be slower from the user's side than a direct access, but it ensures that some entity in the network is acting between users and equipments and checks and ensures their function.

Conclusion

In this document, we examined the possibility to deliver SS7 to the user. It appears clearly that there is a demand for such services in the user applications.

The main application that can be made of this service is Network Management. The user can control and monitor some parts of the public network, which is a problem that the actual carriers will have to address.

The way it could be solved is by adding a control entity, to the already existing Management Center for example, and to deliver classes of management services to the user, with quality and contract negotiation.

However we suggest that OA&M be delivered to the user, this can be reexamined when the draft documents specifying the functions available in this module will have been produced.

Bibliography

- [1] ISDN, William Stallings, MacMillan 1989.
- [2] " ISDN user-network interface management protocol and its applications ", H. Ishii, Globecom 88, vol 1, 198-202.
- [3] " Network based business services : evolution and deployment". Tilak R. Sikri et al., International Switching Symposium 87, vol 2, 352-356.
- [4] " Exploiting the Power of Common Channel Signaling System n.7 : Network Capabilities and New Signaling Network Switching Technology ". M.A. Kollmorgen, P.R. Miller, R.L. Simms, IEEE 1987, p.118.

**Technical Issues in Evolving to
Integrated Services
Digital Networks (ISDN)**

Appendix D

Personnel Involved

College of Computing

Philip H. Enslow

Mostafa Ammar

Ian Akyildiz

Ronald Hutchins

Kimberly Kappel

Abe Iskac

Koo-Don Chung

Remi Alquier

Electrical Engineering

Aubrey Bush

Douglas W. Browning

Mary Ann Ingram

Chin Tau Lea

Gordon L. Stuber

Stephen B. Wicker

Serena Zabin

Jeffrey S. Hankin

**Technical Issues in Evolving to
Integrated Services
Digital Networks (ISDN)**

Appendix E

Initial Project Meeting

ISDN

A Brief Introduction

Presentation at the Conference
"ISDN in the Army: What are Realistic Expectations"

Sponsored by
The U.S. Army Institute for Research in
Management Information, Communications
and Computer Sciences

9 March 1989

Philip H. Enslow Jr.
School of Information and Computer Science
Georgia Institute of Technology
Atlanta, Georgia 30332
(404)894-3187

ISDN — What It Is

Integrated Digital Access to ALL Services

Potential for increased subscriber control

A series of
CCITT Recommendations— The "I-Series"
Amplified by U.S. Standards — T1

Telecommunications Services

Telematic Services

ISDN — What It Is NOT

Not a sudden change of the entire system
Primarily evolution of the existing systems
Already here:

Digital Trunking
Digital Switches
The IDN

Major changes yet to come:
Integrated and Digital Access
New Subscriber Access Protocols
Increased Subscriber Control Capabilities

Not a major change in Sub Telecom Services
Ex: 32 kbps voice is not "ISDN"

"2B + D"

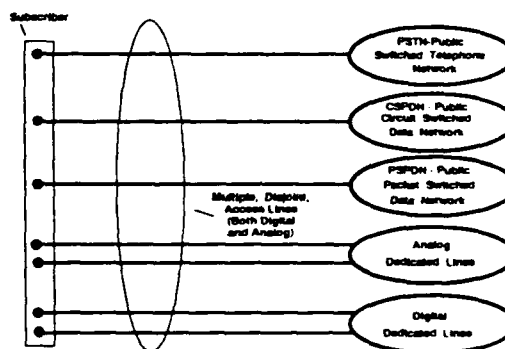
To Do Is To Be — Aristotle

To Be Or Not To Be — Shakespeare

Do Bi Do Bi Do — Sinatra

Two B Plus D — CCITT

Present Service Access



ISDN Subscriber Services Available

Telecommunications

Telematic

ISDN Telecom Services Available

Switched Voice

Switched Digital

Dedicated Pt-Pt Lines

Packet Switched Digital -
Dedicated Line Access
Switched Line Access
Shared Line Access

Major Changes in Subscriber Interface

Delivery

Uses existing 2-wire distribution loops
Digital signal delivered to subscriber
Multiple service channels over one physical path
Variety of services available on each channel

Signaling and Control

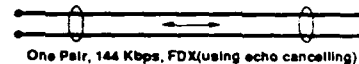
Out-of-Band (c.f. present In-Band)
Shared Control Channel
Increased control capabilities

The ISDN Subscriber Interfaces - Types of Channels and Their Uses

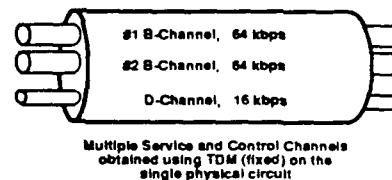
- B - PCM Voice
Wideband speech (7 kHz)
Image (single frames)
Digital Data (to 64 kbps)
Subrate digital data (less than 64 kbps)
- D - Signaling for B or Wideband Channels
Packet type data (as available)
Telemetry (as available)
- H - High quality audio
Video
High speed digital data

The ISDN Subscriber Interfaces - The Basic User Interface

Physical

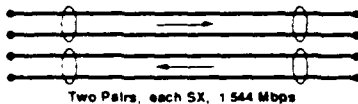


Logical

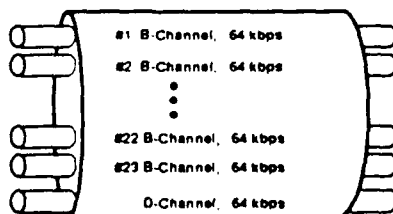


The ISDN Subscriber Interfaces - The Primary User Interface

Physical



Logical

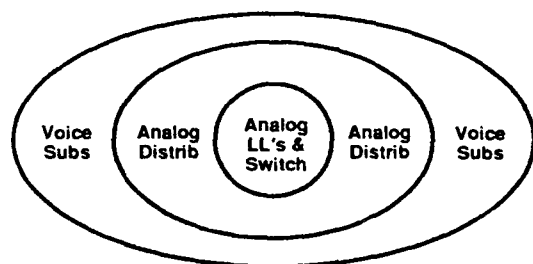


ISDN Telematic Services Available

Videotex

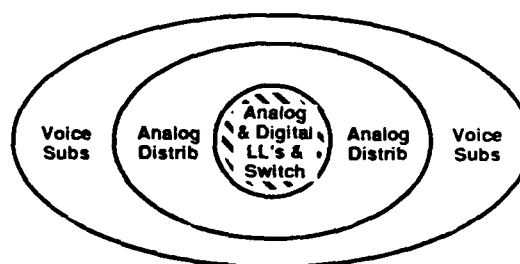
On-Line Data Bases

Putting ISDN Into Perspective Its Evolution - Step 1



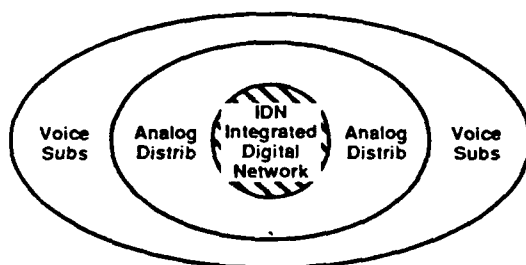
An All Analog Plant
(4kHz channels)

Putting ISDN Into Perspective Its Evolution - Step 2



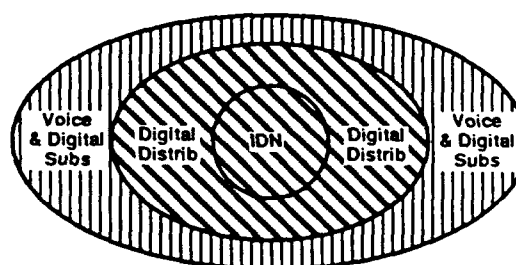
Introduction of Some Digital Subsystems
(4 kHz & 64 kbps channels)

Putting ISDN Into Perspective Its Evolution - Step 3



All Digital Except for Distribution
(4kHz & 32/64 Kbps Channels)

Putting ISDN Into Perspective Its Evolution - Step 4



"The ISDN"
(All 64kbps channels)

Putting ISDN Into Perspective Comments on Results of Evolution

1. Voice orientation of most subsystems and the evolution results in service channels of 64 Kbps or multiples of 64 Kbps.
For voice — too big (for current voice tech)
For data — too small (for many new apps)
2. 32 kbps voice being introduced
 - Problems for use with some modems
 - Not an "ISDN" product but being "blamed" on ISDN

Key ISDN Technologies

Digital Subscriber Lines
Transmission Technology
Processing Technology

User Interfaces

ISDN Switch — Cost-Effective

The "ISDN" An Enhanced Capability Central Office

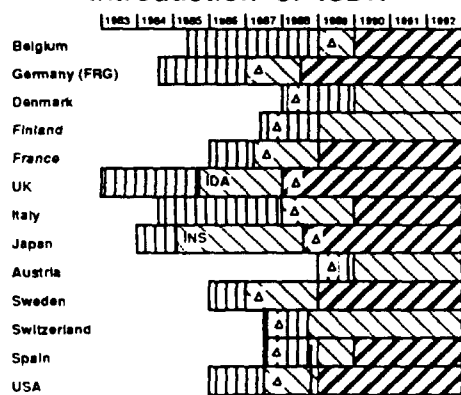
The ISDN is one of the major and critical components of the ISDN evolution

New capabilities required in the ISDN switch:
Handle digital subscriber lines
Handle user control
Support shared use of the D-channel

Evolving to the ISDN Potential Problems

Definition of user interfaces
ISDN Compatible Subscriber Terminals
Attraction of Services Available
Local loop transmission capabilities
Tariffing and Charges
Signaling System #7 deployment
Termination of Primary Rate Access
Subrate multiplexing standards
Ability to insure 64 Kbps end-to-end

Introduction of ISDN



Introduction of ISDN (con't)

Δ ISDN according to CCITT basic access (B64 + B64 + D16) and primary rate access (30 X B64 + D64) or (23 X B64 + D64)

IDA Integrated digital access with B64 + B8 + D8

INS Information network system with B64 + B16 + D8



ISDN — Technical References

Ronayne, John, The Integrated Services Digital Network: from concept to application, Pitman, London, 1987

Stallings, William, ISDN: Technology, Applications, and Standards, Macmillan (to be publ), New York, 1988

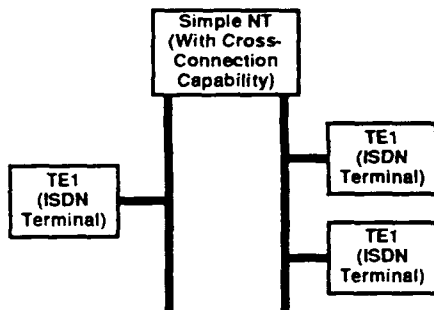
Performance and Applicability of ISDN User Services

Performance and Applicability of ISDN User Services

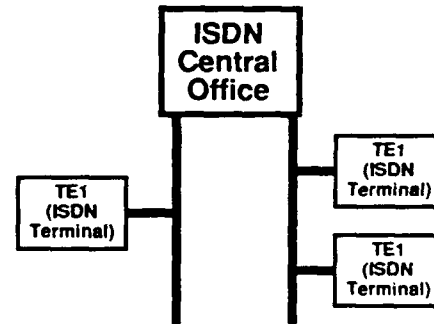
Major Activities

- Detailed analysis of protocols
- Develop performance models
- Prepare and run simulation models
- Develop loading & test instruments
- Assemble experimental facility
- Perform measurement tasks

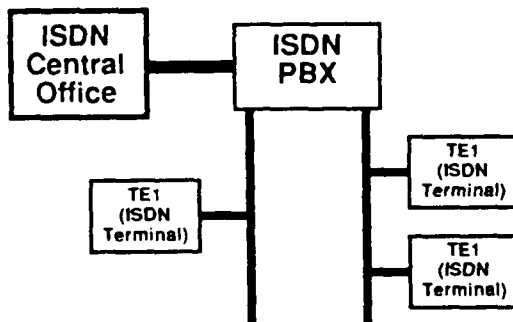
Experimental Facility — Phase 1 (For Familiarization and Instrument Development)



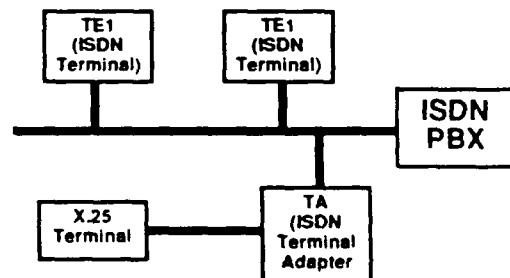
Experimental Facility — Phase 2 (For Flexible Interconnection and Central Office Access)



Experimental Facility — Phase 3 (For Flexible Interconnection and Primary Rate Access)



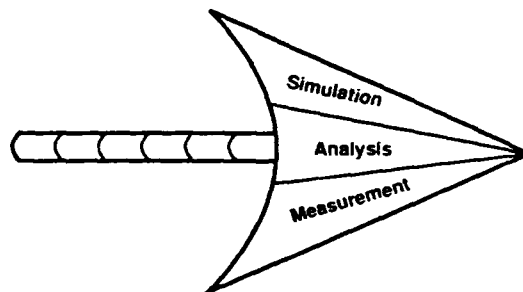
Experimental Facility — Phase 4 (For Use of Existing Terminal Equipment)



General Research Area:

**Performance of
Store-and-Forward
Components and
Systems**

SYSTEM PERFORMANCE STUDIES



Summary of Research Activities:

- Development of functional models
- Establishment of suitable metrics
- Development of analytic models
- Simulations
- Development of loading and measurement instruments
- Perform experimental studies

Performance of a Local Area Network System

Results: Performance of a Local Area Network System

- The delays caused by the virtual circuit processes were 1,000 time larger than those attributable to cable access and transmission.
- The delay values were strongly clustered around multiples of 30 ms.

Performance of a Token Passing Ring Repeater/Extender

Results: Performance of a Token Passing Ring Repeater/Extender

- The encoding scheme utilized on the fiber link caused cascading of errors, i.e. long error bursts
- The encoding scheme was incompatible with DS2 framing
- Some of the TPR adapter cards could not operate with maximum specified delays

**Technical Issues in Evolving to
Integrated Services
Digital Networks (ISDN)**

Appendix F

November 1989 Project Review

***"Technical Issues in
Evolving to
Integrated Services
Digital Network (ISDN)"***

Contract Number: DAKF11-86-D-0015-0022

GIT Project Numbers:

E-21-F31(Elec Engr) and G-36-615 (ICS)

***GIT — ISDN Research
Project
BellSouth Interests***

GIT Project Number:

G-36-622

Establishment of ISDN Experimental Facility

- The Central Node (ICS)
 - .. ISDN PCs
 - ... AMD Boards (Limited software capabilities)
 - ... Hayes Boards (Limited software capabilities)
 - ... Northern Telecom Boards (With software)
 - ... Teleos Boards (Compatibility with Teleos Switch Simulator)
 - ... Vadis Boards (Extensive software capabilities)
 - .. ISDN Telephones
 - ... Northern Telecom (4 instruments)
 - ... ISDN Telephone Kit (Experimental modification capability)
 - .. Switch Simulation
 - ... AMD Boards (Very Limited)
 - ... Teleos (Extensive Capabilities)
 - .. "Real" ISDN Lines
 - ... Southern Bell (Extensive negotiations)
 - .. Internal Distribution
 - ... Patch Panels
 - ... Wiring and Connectors
 - .. Protocol Test and Monitoring Capabilities
 - ... Tekelec (Negotiating)
 - ... Teleos Switch Simulator (Includes test and monitoring)
 - ... Southern Bell (Loaner)
 - ... Alcatel/STR (offer to beta test and development participation)
 - ... S-Bus Repeater/Error Injector (In-house development)
 - .. Performance Loading and Test Capabilities
 - ... Character Timer (In-house development)
 - ... X.25 Packet Timer (In-House development)
 - ... Alcatel/STR (offer to beta test and development participation)
 - .. Higher Level Software
 - ... Touch Communications (Source of GOSIP and ISDN S/W)
 - ... Vadis (some capability)

- The AIRMICS Node
 - .. ISDN PCs
 - ... Zenith PCs (On-order)
 - ... AMD Boards (Limited software capabilities)
 - ... Northern Telecom Boards (With software)
 - ... Teleos Boards (Compatibility with Teleos Switch Simulator)
 - ... Vadis Boards (Extensive software capabilities)
 - .. ISDN Telephones
 - ... Northern telecom (1 instruments)
 - .. Switch Simulation
 - ... AMD Boards (Very Limited)
 - ... Teleos (Extensive Capabilities)
 - .. "Real" ISDN Lines
 - ... Southern Bell (Extensive negotiations)
 - .. Internal Distribution
 - ... Wiring and Connectors
 - .. Higher Level Software
 - ... Touch Communications (Source of GOSIP and ISDN S/W)
 - ... Vadis (some capability)
 - .. Protocol Test and Monitoring Capabilities
 - ... Tekelec (Negotiating)
 - ... Teleos Switch Simulator (Includes test and monitoring)

- The EE Node
 - .. ISDN PCs
 - ... PCs (To be ordered)
 - ... AMD Boards (Limited software capabilities)
 - ... Northern Telecom Boards (With software)
 - ... Vadis Boards (Extensive software capabilities)
 - .. ISDN Telephones
 - ... Northern Telecom (1 instruments)
 - .. "Real" ISDN Lines
 - ... Southern Bell (Extensive negotiations)
 - .. Internal Distribution
 - ... Wiring and Connectors
 - .. Higher Level Software
 - ... Touch Communications (Source of GOSIP and ISDN S/W)
 - ... Vadis (some capability)

Significant Activities

- **Held Joint Kick-off Meeting with AIRMICS (9 March, 1989)**
 - Resulted in Increased Industry Participation (AT&T, NTI, Teleos)
- **Finalized Participation by BellSouth Enterprises**
 - Provided Major Funding for Personnel
 - Provided Some Funding for Equipment
 - Provided Complete Funding for ISDN Lines
- **Moved to New Quarters**
 - Office made available for AIRMICS and BellSouth
 - Co-Location of EE and ICS Network Groups
 - Access to Campus Fiber Network
- **Personnel Changes**
 - Hired Kimberly Kappel, Network Management
 - Ed Coleman, Full-time Infrastructure

Projected Interconnection Studies

- **ISDN over DS-1**
 - .. Utilizing DML-45, Campus Fiber, and BRITE Cards
 - .. Interconnect Central Node and AIRMICS
- **ISDN Gateway to ETHERNET**
 - .. Using Vadis Cards and NEXT Machine
- **ISDN Gateway to X.25**
 - .. Teleos Box
- **ISDN Gateway to GOSIP**
 - .. Touch and ISO/DE

Research Projects

- **AMD Experiments (Ron Hutchins)**
 - Identified software limitations of these boards
 - Identified incompatibility problems with other ISDN boards
- **Mitel Experiments (Abe Iskac)**
 - Appear to be of minimum long-term value
- **"Analytical Studies of D-Channel Traffic" (Koo-don Chung)**

**Technical Issues in Evolving to
Integrated Services
Digital Networks (ISDN)**

Appendix G

March 1990 Project Review

Welcome

to the

Georgia Tech
ISDN Research Project

In-Progress Review

15 March, 1990



Agenda

- | | |
|-----------|--|
| 1:00-1:15 | Registration |
| 1:15-1:30 | Welcome
Jay Gowens, AIRMICS
Neale Hightower, BellSouth |
| 1:30-2:00 | What is ISDN
Phil Enslow, GIT |
| 2:00-2:20 | Project Introduction and Overview
Phil Enslow, GIT |
| 2:20-2:40 | Break |
| 2:40-3:30 | Project Results and Plans
Phil Enslow, GIT |
| 3:30-4:00 | AIRMICS Meeting (DOD)
Jay Gowens, AIRMICS |
| 3:30-4:30 | Demonstrations
Ron Hutchins, GIT |



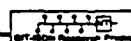
What is ISDN?

A Very Brief Introduction

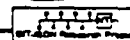
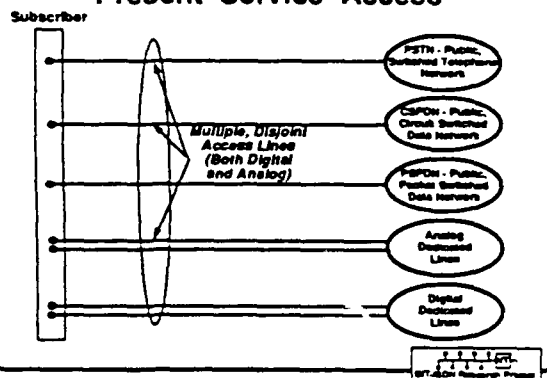


ISDN — CCITT Definition

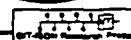
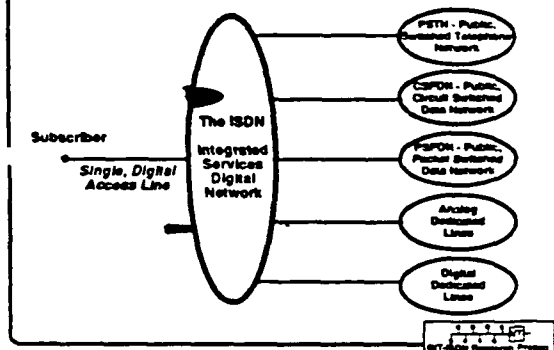
An ISDN is a network, in general evolving from a telephony IDN (Integrated Digital Network), that provides end-to-end digital connectivity to support a wide range of services, including voice and non-voice services to which users have access by a limited set of standard multipurpose user-network interfaces.



Present Service Access

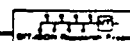


ISDN Service Access



The ISDN Subscriber Interfaces — Types of Channels and Their Uses

- B - PCM Voice**
 - Wideband speech (7kHz)
 - Image (single frames)
 - Digital Data (to 64 kbps)
 - Subrate digital data (less than 64 kbps)
- D - Signaling for B or Wideband Channels**
 - Packet type data (as available)
 - Telemetry (as available)
- H - High quality audio**
 - Video
 - High speed digital data



The ISDN Subscriber Interfaces - The Basic User Interface

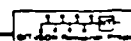
Physical

One Pair, 144 Kbps, FDX(using echo cancelling)

Logical

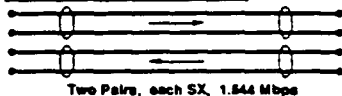
#1 B-Channel, 64 kbps
#2 B-Channel, 64 kbps
D-Channel, 16 kbps

Multiple Service and Control Channels obtained using TDM (time division multiplexing) on the single physical circuit

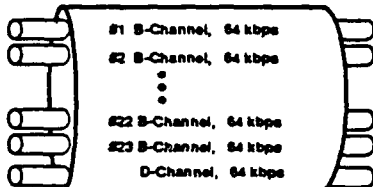


The ISDN Subscriber Interfaces - The Primary User Interface

Physical



Logical

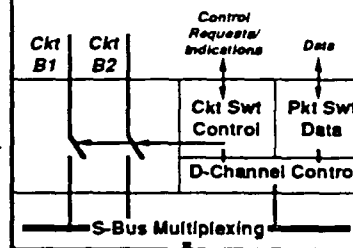


ISDN Resource Project

An ISDN Terminal — "TE1"



Analog-to-Digital Conversion,
Data sources/sinks, etc.



ISDN Resource Project

Major Changes in Subscriber Interface

Delivery

- Uses existing 2-wire distribution loops
- Digital signal delivered to subscriber
- Multiple service channels over one physical path
- Variety of services available on each channel

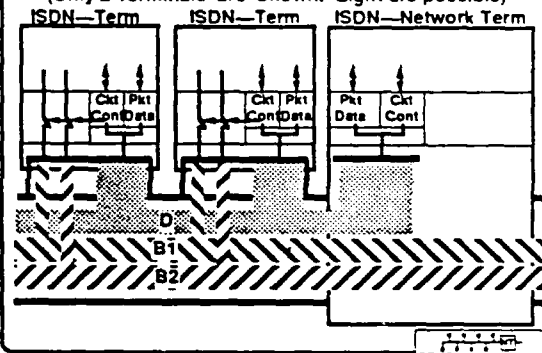
Signaling and Control

- Out-of-Band (c.f. present In-Band)
- Shared Control Channel
- Increased control capabilities

ISDN Resource Project

ISDN S-BUS CONNECTIONS

(Only 2 Terminals are Shown. Eight are possible)



ISDN Resource Project

The "ISDN" An Enhanced Capability Central Office

The ISDN central office is one of the major and critical components of the ISDN evolution

New capabilities required in the ISDN switch:

- Handle digital subscriber lines
- Handle user control
- Support shared use of the D-channel

ISDN Resource Project

Putting ISDN Into Perspective Comments on Results of Evolution

1. Voice orientation of most subsystems and the evolution results in service channels of 64 Kbps or multiples of 64 Kbps.
For voice — too big (for current voice tech)
For data — too small (for many new apps)
2. 32 Kbps voice being introduced
 - Problems for use with some modems
 - Not an "ISDN" product but being "blamed" on ISDN

ISDN Resource Project

ISDN — What It Is

Integrated Digital Access to ALL Services

Potential for increased subscriber control

A series of
CCITT Recommendations — The "I-Series"
Amplified by U.S. Standards — T1

Telecommunications Services

Telematic Services



ISDN — What It Is Not

Not a sudden change of the entire system

Primarily evolution of the existing systems

Already here:

Digital Trunking

Digital Switches

The IDN

Major changes yet to come:

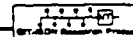
Integrated and Digital Access

New Subscriber Access Protocols

Increased Subscriber Control Capabilities

Not a major change in Subscriber Telecom Services

Ex: 32 Kbps voice is not "ISDN"



Introduction to the Program

GIT-ISDN Research Project

In-Progress Review

15 March, 1990

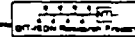
School of Electrical Engineering
School of Information and Computer Science
Georgia Institute of Technology
Atlanta, Georgia



A Joint

Government, Industry, University

Research Program



Project Goals and Objectives

Current Set

Determine and characterize the performance characteristics of ISDN user services

Evaluate the applicability of ISDN services to support user service needs

Compare potential ISDN services to existing services

Develop a comprehensive ISDN knowledge base

Develop and evaluate transition strategies for the future



Primary Research Tasks

Initial Set

Develop analytic and experimental tools for performance testing and evaluation

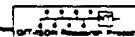
S-Bus simulator
B-Channel, D-Channel loader/tester
Physical Layer error injector

Perform Performance Tests

ISDN Packet handler — delay, throughput, errors
D-Channel service for data transport
B-Channel service for data transport
Comparison of B & D-Channels for data transport
Switched B-Channels for voice and data transport

Evaluate the applicability/suitability of ISDN services

Matching user application requirements to ISDN (BRI, PRI, LAN, FDDI)
Integrating local (post, campus) ISDN with WANs
Utilizing ISDN to interconnect/extend LANs
Comparing FDDI/FDDI-II to B-ISDN



Sponsoring Organizations

U.S. Army Institute for Research in Management,
Information, Communications, and Computer Sciences

BellSouth Enterprises, University Programs

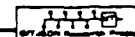
Advanced Micro Devices

AT&T

Northern Telecom

Teleos

Vadis



Key Personnel

Principal Investigators:

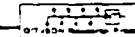
Prof Aubrey Bush (404)894-2942
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Faculty Researchers:

Ian Akyildiz (404)894-5141
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Stephen Wicker (404)894-3129

Principal Staff:

Ed Coleman (404)894-4465
Ron Hutchins (404)894-3612
Abe Iskac (404)894-3146
Kim Kappel (404)853-9383



Project Results

In-Progress Review

15 March, 1990



Project Results

Outline

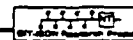
Establishment of the ISDN Experimental Facility

Installation of ISDN Hardware, Software, and Services

Utilization of ISDN Services

Studies of ISDN Protocols

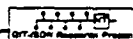
Preparation of an ISDN Users' Handbook



Establishment

of

ISDN Experimental Facility



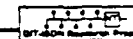
ISDN Experimental Facility

Goals and Objectives

Create an Instrumented ISDN Applications Test Facility that will support the detailed examination of ISDN services and their applicability

Record and examine the problems encountered in installing and utilizing ISDN services

Support experimental studies of ISDN protocols



ISDN Experimental Facility

Hardware Capabilities

ISDN Telephones

ISDN Speech + Data Terminals

ISDN Central Office lines

ISDN Switch Simulators

Basic rate interfaces

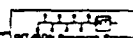
Primary rate interconnection of switches over fiber

ISDN Protocol Analyzers

Load Generation and Measurement Devices

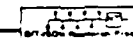
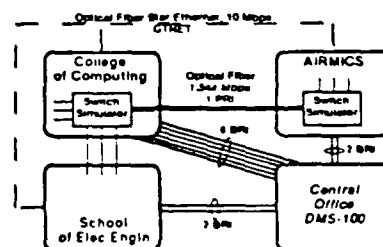
Packets and Characters

ISDN S-Bus Error Injector



ISDN Experimental Facility

Physical Layout



ISDN Experimental Facility

Development of Special Test Equipment

Load generators and testers
Throughput and Delivery Delay
Characters and Packets

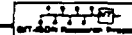
Error/Noise Injectors
S-Bus



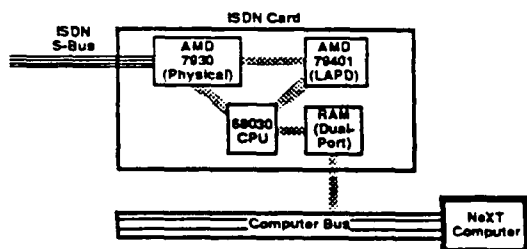
ISDN Experimental Facility

Development of Special ISDN Interfaces

NeXT Computer ISDN Interface Board
Hardware
Software



NeXT Computer ISDN Interface Board



ISDN Experimental Facility

Functional Capabilities

Provide several levels of connectivity
Local
Campus
Public Network

Full experimental freedom
Totally isolated, local and campus connections

Test applicability of ISDN to specific applications

Operational test of ISDN hardware and software

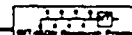


Installation of ISDN Hardware, Software, and Services

PC ISDN Terminal Adapter Boards

ISDN Central Office Lines

Office Distribution of ISDN Lines



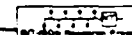
ISDN Hardware and Software

PC ISDN Terminal Adapter Boards

Hardware compatibility problems
Clock rates
Designation of the ISDN port
Conflicts with other devices

Software Interfaces
Varied, Non-Standard
Two "NETBIOS" not the same

We have not yet achieved
Interoperation between two
vendors



ISDN Hardware and Software

Ordering and Using ISDN Lines

Features/options available
Very large number available

Necessity to completely specify the configuration

Assignment of B-Channels to Terminals
Not dynamic
Must designate "Packet B" or "Circuit B"

Allocation of telephone numbers (DNAs)
Limits number of devices allowed on bus



ISDN Hardware and Software

Office Distribution of ISDN Lines

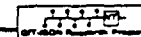
Cable/Wire sizes
Problems with crimp/screw connectors

Connectors
Use of RJ-11s and RJ-45s

Terminating and Testing
New ISDN "punchdown" blocks

Topology
Logical/electrical bus
Physical star
Problems of length

Several Mysteries!!!

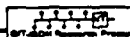


Utilization of ISDN Services

Summary

Utilizing a PC on ISDN

Error recovery times

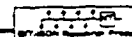


Utilization of ISDN Services

Utilizing a PC on ISDN

Problems of memory requirements
Some ISDN software packages quite large
Applications limited by DOS memory limit (640K)
Will OS/2 or UNIX be required for ISDN applications?

What software features to include
Are ISDN software packages provide many
Problem is making a "good" selection

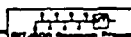


Utilization of ISDN Services

Error Recovery

Reaction to intentionally forced errors
Duplicate TEI assignment
Central Office switch resets and runs diagnostics
—15 mins or so
Disconnect - as moving a phone
Interpreted as LINK DOWN and CO resets

Results of system errors not yet observed



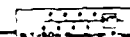
Studies of ISDN Protocols

Summary

Analytic Studies

Simulations

Protocol Stability and Robustness



Studies of ISDN Protocols

Analytic Studies

D-Channel Access Protocol
Priority and Round Robin Servers
Multiple Queues

D-Channel Data Transfer Protocols
Effects of high loading — long ACK delays

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ISDN Research Project

Studies of ISDN Protocols

Simulations

D-Channel Data Transfer Protocol

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ISDN Research Project

Studies of ISDN Protocols

Protocol Stability and Robustness

Protocol Initiation

Protocol recovery
Same TEI assigned to two TE's — minutes!

Work in this area is of high concern
and is just starting

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ISDN Research Project

Preparation of ISDN Users' Handbook

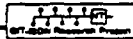
This will be a collection of facts,
experiences, tips, etc. acquired
during all phases of this project

1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1
ISDN Research Project

Project Plans

In-Progress Review

15 March, 1990



Project Plans

Summary

Exploitation of The Experimental Facility

Integrated ISDN Connectivity

LANs and ISDN

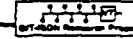
Development of Standard ISDN Software Interface

Development of operational test specifications

Use of ISDN in private networks

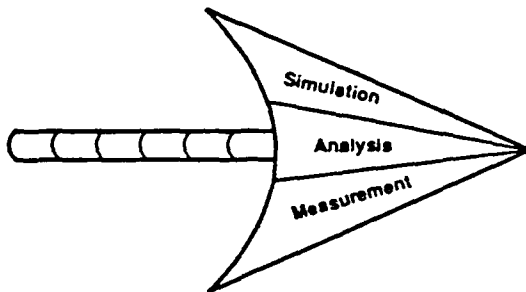
Control interfaces to/from Public ISDN Networks

"Technical" Participation in the NIU



Exploiting the Experimental Facility

System Performance Studies

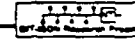


Integrated ISDN Connectivity

The user of ISDN services must be provided with the same interface as the user of all other interconnection services.

A variety of special procedures is unacceptable.

Work is required to develop a consistent and common user interface.



Project Plans

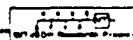
LANs and ISDN

What will be the role and usefulness of ISDN with respect to Local Area Networks?

Interconnect (bridge) between two LANs

Extend a LAN

Replace the LAN



LANs and ISDN

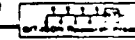
Interconnect two LANs



Extend a LAN



Replace the LAN



Project Plans

Development of Standard Software Interface ISDN-API (Application Program Interface)

Today, multiple interfaces to TA Boards are encountered
Between Vendors
Within one Vendor
One Vendor has 4 different interfaces

Lack of a standard ISDN-API is a great impediment to
production of ISDN applications packages

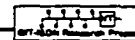
Target environments
GOSIP (OSI)
TCP/IP
De facto standards -
NETBIOS, UNIX, NOVELL, etc.



Project Plans

Development of Operational Tests Specifications

A set of comprehensive acceptance and
type classification tests have to be
prepared to assist users in verifying the
interconnectability, interoperability, and
performance of various pieces of ISDN
hardware and software.



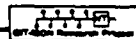
Project Plans

Control Interfaces to/from ISDN

Individual Subscriber to/from Public ISDN Networks

Private Networks to/from Public ISDN Networks

"Control" of Private Networks implemented on
Public ISDN Networks (Virtual Private Nets)



"Technical" Interaction with the NIU

The users need to be represented by
a stronger "technical" voice such as
university personnel.

